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VARIOUS PHASES OF THE ROAD QUESTION.

BY ROY STONE,
Director, Office of Road Inquiry.

Read February 5, 1898.

I take it for granted, Mr. President and members of the Engineers' Club, that, however eminent as engineers, you are, first of all, American citizens, and that your deepest interest in the road question will lie in that branch of it which concerns all the citizens of this Republic —that is, how to make it possible to build good roads throughout the whole country. When I had the pleasure of addressing the engineering class of the Massachusetts Institute of Technology upon this subject I said:

"There is need, however, in this country, and in this field, for something more than mere technical instruction. Under a paternal government the engineer needs only to know how to build roads; the authorities will do the rest. Under a popular government he must know how to get them built. His duty as a citizen and his professional interest alike require that he should know all about the laws and ways and means, and all the facts and arguments bearing on the question, and be as well able to promote road improvements as to execute them."

In view of these considerations I am sure you will pardon me if I address myself to-night mainly to what may be called the political branch of this subject—questions of legislation, of public finance, and the forming of public opinion.

FIRST, AS TO THE IMPORTANCE OF ROAD IMPROVEMENT.

To you who constantly study the public interests in the direction of public works I could not, perhaps, give any new light on this branch of the subject; but I can, possibly, reinforce your own opinions and arguments by quoting those of other professions and occupations who are equally concerned with you in this direction. The commercial and business interests throughout the country are fairly represented in this respect in the statement of the Chamber of Commerce of the State of New York, as follows:

"The movement for good roads deeply concerns every commercial and financial interest in the land. We are handicapped in all the markets of the world by an enormous waste of labor in the primary transportation of our products and manufactures, while our home markets are restricted by difficulties in rural distribution which not infrequently clog all the channels of transportation, trade, and finance."

The railway interests of the country are equally pronounced in favor of road improvement, and their feeling is well expressed by the Chief Engineer of the Michigan and Grand Rapids Railway of Michigan, who says:

"No interest would be more benefited by good roads than the railroads. During a large part of the year much of their rolling-stock is lying idle because the farmers can not bring their produce to the station. At other times they can not get cars enough to haul away this produce, and sidings, elevators, and warehouses are gorged to overflowing; extra train forces must be employed, men in other lines of traffic who need cars are denied, and general disturbance of business, delay, and loss follow. Good roads would distribute this business more uniformly over the year, to the mutual advantage of companies and their patrons, to say nothing of the increase of population and production and prosperity which would follow."

From the watch-tower of the Press comes this expression, voiced by the Washington "Post":

"The one great public work that now looms up before the people of the United States and imperatively demands attention is road-building—the improvement of old and construction of new highways. It is not likely that there will ever occur another period of railway construction like that through which this country passed in the quarter century succeeding our great war; but it is both desirable and probable that an equally important and scarcely less costly era of road-building has just begun, and will go on for many decads, adding as much to the wealth of the nation and to the comfort and convenience of the masses as the railroads have accomplished in those directions."

Other learned professions, the Law, the Church, and the Educational, are quite as earnest in their advocacy of this reform, though I will not take time to quote their opinions; and even the profession most universally in evidence, that of politics, is thoroughly aroused in this regard. The last State road convention that I attended had in its membership every prominent candidate for legislative and executive honors in the State.

DEFINITE LOSSES BY BAD ROADS.

When the Office of Road Inquiry was organized, 10,000 letters of inquiry were, with the aid of the Division of Statistics of the Department, sent to intelligent and reliable farmers throughout the country, and reports were consolidated from about 1200 counties, giving the average length of haul, in miles, from farms to market or shipping points, the average weight of load hauled, and the average cost per ton per mile; and from these data is deduced the average cost per ton for the whole length of haul.

These returns have been arranged in groups of States, and the result shows that the average length of haul in the Eastern States is 5.9 miles; in the Northern States, 6.9 miles; in the Middle States, 8.8 miles; in the cotton States, 12.6 miles; in the prairie States, 8.8 miles; in the Pacific Coast and mountain States, 23.3 miles; and in the whole United States, 12.1 miles.

The average weight of load for two horses in the Eastern States is 2216 pounds; cotton States, 1397 pounds; prairie States, 2409 pounds; Pacific Coast and mountain States, 2197 pounds; and the whole United States, 2002 pounds.

The average cost per ton of 2000 pounds per mile in the Eastern

States is 32 cents; Northern States, 27 cents; Middle Southern States, 31 cents; cotton States, 25 cents; prairie States, 22 cents; Pacific Coast and mountain States, 22 cents; and the whole United States, 25 cents.

The total average cost per ton for the whole length of haul is as follows: Eastern States, $1.89; Northern States, $1.86; Middle Southern States, $2.72; cotton States, $3.05; prairie States, $1.94; Pacific Coast and mountain States, $5.12; and the whole United States, $3.02.

Assuming the correctness of these data, it becomes possible to obtain approximately the total cost of the entire movement of farm products and other classes of materials over country roads.

Taking the census returns of farm products of the United States, and such data as could be obtained regarding the forest and mineral products hauled over the common roads, and estimating the incidental traffic, we arrive at a total of 313,349,227 tons, which, at the average cost stated, $3.02 per ton, makes a grand total for the annual cost of haulage on the public roads of $946,414,665. Our information regarding the cost of hauling in foreign countries and in the few good roads districts of this country indicates that nearly two-thirds of this total is due to the bad condition of the roads.

Furthermore, the increase in cost of haulage actually done is by no means the only loss by bad roads. The loss of perishable products for want of access to market, the failure to reach market when prices are good, and the failure to cultivate products which would be marketable if markets were always accessible—add many millions to the actual tax of bad roads. Moreover, the enforced idleness of millions of men and draft animals during large portions of the year is a loss not always taken into account in estimating the cost of work actually done.

The magnitude even of the direct money loss is greater than the total expenditures of the United States Government, and equals the total cost of the National and State Governments; it is equal to one-quarter of the home value of the farm products of the country, and if the same amount could be applied to road improvement, it would macadamize all the roads of the country in three years.

OBSTACLES TO ROAD IMPROVEMENT.*

The chief difficulty in the way of road improvement in this country is the negative or hostile attitude of the rural population toward all measures calculated to bring them the aid which the cities and corporations are generally willing to give them for this work. Wherever, as in parts of New Jersey, the farmers themselves have come to realize the importance of road improvement and to take steps for the necessary legislation, the actual advance is very rapid. It is important, therefore, to bring home to the attention of the farmers not only the losses which they bear in common with all who consume their products and who help to pay for the waste of labor in transportation, but the absolute injustice which they suffer in being compelled by law, as they are in most States, to build and maintain the roads entirely at their own cost. They do not realize that this is a vicious inheritance from the old country: a system which the people there have cast aside many generations ago. The roads of a country are more necessary to its cities than to its rural population. The farmers could live, at a pinch, on what they raise, but the cities raise nothing, and if the country roads were to disappear, the people of the cities must scatter in a day to find the bare necessaries of life. The farms of the United States comprise less than one-fourth of the total property of the country, yet they have been charged with the entire cost of maintaining the highways for the whole people.

Another obstacle to the advance of road improvement is the general overestimate of the necessary cost of country roads. A few years ago the stone roads built in New Jersey cost in the neighborhood of $10,000 per mile. At present roads equally good are built there in some cases for $3000 per mile, even where railroad transportation of materials is required; but in localities better supplied with road material and contented with narrower roads, very good stone roads are now being built for even less than half of the latter amount. Experience, again, has demonstrated very clearly that in most country districts a single-track stone road, not more than eight or ten feet wide, with a good earth track on one or both sides, gives better satisfaction than a double track of macadam. The original cost is thereby reduced nearly one-half, and the cost of repairs very much more than one-half, since the stone road is only used in wet weather, when it is in the best condition for wear, and customary injury by traveling in dry weather is avoided. This plan gives, moreover, a constant choice between the earth and stone roads, and the earth road being only used in dry weather loses practically nothing by wear.*

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* The conclusions of the United States Road Inquiry as to the losses by bad roads throughout the country are confirmed with remarkable exactness by the three separate investigations made by the Secretary of the Farmers' National Congress, the author of the "New York State Highway Manual," and the Professor of Engineering at Purdue University, Indiana.

The difficulty that was feared under this method of construction, in the passing of loaded teams in wet weather, has not materialized. It practically never happens that any number of teams meet exactly in the same spot, and consequently there are no tracking and no ruts made by turning, and the earth road, not being used when it is wet, is always hard enough to turn one wheel out upon. Roads of this class have been built in regions where stone is abundant in fields and fences, and where the general grading and ditching is already done, for about $1000 per mile.

PRACTICABLE METHODS FOR ROAD IMPROVEMENT.

Having convinced the farmer and his legislative representative that it is safe and profitable for him to accept the help of his fellow-citizens in the improvement of the highways, you must be prepared to suggest practicable and practical methods for the application of this help. The only plan by which the help of cities, and of business corporations generally, can be given to road-building is through *State aid.* The general coöperative system adopted for State aid is based upon the ideas of "helping those who will help themselves" and of

---

* "The road that would seem to fill the farmer's needs, all things considered, is a solid, well-bedded, stone road, so narrow as to be only a single track, but having an earth track alongside. A fine, dry, smooth dirt track is the perfection of roads ; it is easy on the horses' feet and legs, easy on vehicles, and free from noise and jar. It holds snow better than stone or gravel, and requires less snow to make sleighing ; and where such a track has a stone road alongside to take the travel in wet weather, it will suffer hardly any appreciable wear. The stone road, on the other hand, wears by the grinding of the wheels and the chipping of the horses' calks in dry weather more than in wet. If it can be saved this wear for an average of six months in each year, so much will be clear gain."—*From "Best Roads for Farms and Farming Districts."*

"first come, first served." This plan avoids the local jealousies that would arise from direct State road-building, in which the localities to be chosen might be determined by favoritism, politics, or influence; it leaves the initiative in every case to the local population, and carries with it no sort of compulsion.

The appropriations proposed for State aid vary from twenty-five per cent. in Virginia to seventy-five per cent. in Massachusetts, and in all cases some provision is made for *State supervision* of location and construction. The necessity of this provision is very apparent in much recent improved road construction under local authority. Large sums have been wasted by the macadamizing of steep hills, and worse than wasted, for it has fastened the roads where they are, perhaps for all time to come, by the heavy expense incurred upon them.

Another very effective form of State aid is found in the proper use of *convict labor.* There are local and sectional differences of opinion as to the propriety of working convicts on the public roads, but there is a general consensus as to the feasibility and entire fitness of using them to *prepare road materials* in places where they may be guarded and secluded as cheaply and as perfectly as in the prisons. This plan has been adopted in California at the suggestion of the Office of Road Inquiry, and is entirely successful. Under favoring conditions prepared material can be furnished in this manner and put on cars for about twenty cents per ton, paying the entire cost of maintaining the convicts. An essential feature of this plan is the securing of cheap *railway transportation.* This was done in California by an agreement in advance with the railways of the State to carry this material at the bare cost of train service. As a result, the valley counties in California, where neither stone nor gravel is to be found, are beginning to build roads at a cost far below that usually necessary in the most favored districts. This plan solves, to a great degree, the convict labor question as well as the road question. Instead of competing with free labor, it stimulates the employment of such labor in actual road-building by furnishing cheap materials for the purpose.

NATIONAL AID.

Although in its earlier days this nation was, for its size, the greatest road-builder in the world, and although there is little question as to the great national advantages of road improvement, it would be extremely difficult now to secure even a moderate provision of direct national aid, more especially as this idea has been seized upon by politicians of a certain grade in order to bolster up their own schemes of national finance.

But there is one direction in which the general government can aid most powerfully in road-building without expense or risk, and I may be pardoned if I present that method to you in some detail.

INVESTMENT OF POSTAL SAVINGS IN ROAD BONDS.

Many able statesmen have proposed that this Government should follow the example of nearly all the others in the establishment of postal savings-banks. The present Postmaster-General devoted nearly one-third of his annual report to this subject. He admitted, however, the existence of some difficulty in finding a proper investment for the funds, and, having always in view the finding of means for road improvement, I took the opportunity to commend to him the investment of these savings in bonds issued especially for road-building, saying that:

> "Such bonds are the very safest of investments, since their avails, properly applied to road improvement, will vastly increase the value of property in the country, and the bonds thus multiply their own security.
>
> "One great advantage of this arrangement would be that the money deposited in country districts would come back into circulation there, forming an 'endless chain' of benefits.
>
> "A further advantage, from the road-building point of view, would be that the poor and sparsely settled counties would get their road money at as low a rate of interest as those which are rich and populous.
>
> "The Government could be further secured by the State's guaranty of the bonds, by its own supervision of the road-building, and, if necessary, by the State's conferring upon it the right to collect tolls on the roads in case of default in payment of interest or principal."

The general scheme of establishing postal savings-banks finds many supporters and few opponents, except upon the score of the difficulty of finding investments or the interference with commercial savings institutions. The plan of investing in road bonds appears to remove the investment difficulty and to add great strength to the proposition.

No other possible use of money on a large scale can be of greater advantage to the people of the United States. The benefits to be derived from country roads are more universal in their character than those from any other source, except, perhaps, good schools.

BENEFITS TO FARM PROPERTY BY ROAD IMPROVEMENT.

The increase in cash values of the adjacent farms, due to the building of macadam roads, has been frequently estimated at $20 per acre; this estimate is based upon the average hauling of farm products and supplies and the actual saving therein, by good roads, of one dollar per acre annually; it is confirmed by actual experience in many localities in the United States; applied to the million square miles, or 640,000,000 acres, in this country, the increase of value would reach the astounding total of $12,800,000,000.

OBJECTIONS TO THE POSTAL SAVINGS PLAN.

The objections made in behalf of *commercial savings-banks* will have little weight as against the general public interest; indeed, they are very ill-founded even from a purely selfish point of view. The postal savings-banks will reach an entirely new field, in vast districts of the United States where commercial savings-banks do not exist. The average distance from a post-office to the nearest savings-bank ranges in different sections of the country from ten miles to fifty-two miles, and the average for the whole United States is thirty miles. The money that will be drawn out of its hiding-places in the rural districts, where it is now idle and useless, as well as dangerous to its holders, will, if applied as we propose, stimulate industry and thrift among the rural population, increase their purchasing power and their demand for manufactured products, while ultimately it will give them the greater savings due to road improvement to invest in the purchase of these products in cities and towns, where the commercial savings-banks will reap the harvest of their expenditure.

To invest these savings in Government bonds would carry the money to the great financial centers for the purchase of existing bonds, or to the Treasury at Washington for new issues. In either case the money would be slow to get back to the country, where it is needed. The same would be true of investments in State and municipal securities, while the purchase of road improvement bonds would insure the employment of every dollar in payment for labor in the country districts. Nor would the advantages of this employment be confined to those districts, for the money paid out among farmers for the employment of teams and men is applied at the fountain-head of all business, and works its way down through all the channels of trade, production, manufacture, and exchange, turning itself over and over many times in the purchase and transportation of goods and the payment of debts.

Another peculiar benefit from this method of investment will be recognized by those who have watched the construction of a railroad through a difficult country and have seen the wave of improvement due to the money paid out for labor. Nearly every dollar of this money shows itself in farm improvements or the payment of mortgages. It is practically surplus earnings, by those who are making their living otherwise and can lay aside all they receive in this way. The effect of road-building would be the same on a larger scale, since it would be more general. The greater share of the amount paid will be surplus earnings, or "clean money," and, in default of a better investment, will go back into the savings-banks, to be reinvested in the same manner and start again on its round of usefulness.

It is impossible to believe that so vast an increase in the public wealth and so great a stimulus to commercial activity of the whole country could be a disadvantage to banking interests of any kind, and it would seem to be a wise plan on their part, instead of placing themselves in opposition to the public demand in the rural districts for postal savings-banks, to put themselves in active support of such banks upon the condition of the investment of the deposits in road improvement.

The objection of "*Paternalism*" is a sentimental one, and should weigh little against the great practical benefits of the plan from both sides—the saving and the spending.

It may safely be said that this word (long so dreadful) carries, of late, less and less terror to the people of the country, as the practical usefulness of their general government takes more and more varied forms; and the feeling is becoming general that the central government is as much the servant and instrument of the whole people as the State and local governments are of their portions, and that the whole people can as safely use their general government for the general benefit as any section can its local government for local benefit.

Another objection, which can hardly be called a serious one, though it may have some temporary weight, is that the plan proposed smacks of "*Populism.*"

The fact that some Populists have proposed to have the Government build roads and pay for them with fiat money, in order to increase the circulating medium, is no good reason why States and counties should not issue bonds for road-building nor why the Government should not buy these bonds for the postal savings if they are good security. There is no sort of likeness between the two schemes.

Moreover, it would be very unwise to give the Populists a needless grievance by denying them what is just, reasonable, and feasible; on the other hand, it is wiser to go to the very limit in this direction, and so narrow the scope of their demands that the remainder may be insufficient to support a political organization. There is no question that the people of the rural districts need to have their condition improved, and that they will continue discontented and disturbed until some relief is afforded; but if the Government can give them at one stroke the benefits of the postal savings-banks and the home spending of one or perhaps two hundred millions of money annually, with the immediate prospects of good roads and the consequent free delivery of mails, it will be a long step in the betterment of their condition.

It must be noted, too, that this plan will not increase taxation, even for the rebuilding of all the important roads of the United States. The interest on the bonds can be paid out of funds already raised for road repairs and still leave enough to keep a system of good roads in order. The present taxation for road repairs in money and labor throughout the United States amounts to $45,000,000 annually. One-third of this sum, well applied to the daily care of well-built roads, would be quite sufficient to maintain them; the remaining $30,000,000 would pay the interest at two per cent. per annum on $1,500,000,000, which would build 1,000,000 miles of good country roads. Two per cent. is the rate of interest proposed to be paid by the postal savings-banks, and the Post-office Department can well afford to loan the money for roads at the same rate, since it will save more through the improvement of the 276,000 miles of post-roads over which it carries the mails than it will cost to handle the postal savings money.

Roads of the Future.

Having dwelt at length—perhaps a wearisome length—upon matters non-professional, I will close with a few remarks more appropriate to an audience accustomed to contemplating great public works and great feats of constructive skill, and in this connection I can not do better than to quote what I said to the young engineers at Boston. After reciting various methods of road improvement, I said:

"Under these various methods roads enough will undoubtedly be built so much better than those at present existing in this country as to pave the way for building better and more costly roads in the future, and, while I urge on young engineers to be prepared to build these cheaper roads chiefly for their educational advantages to the public, I do not by any means desire to lower the ultimate standard of road-building. The great highways of the future will undoubtedly be better structures than anything in the present or the past, and fully worth a trained engineer's most earnest study and attention. Undoubtedly, the wearing surfaces of stone or asphalt will be replaced by flat steel rails suited to all vehicles and laid level with the roadway, so that wheels will pass on to or off them with slight difficulty, the inner edge being raised only enough to give a gentle guidance to the wheels.

"There is no more economy in running a wagon over earth and stones than there would be in so running a railway train, and the saving in wear on roads of heavy travel, with the present low price of steel, would alone more than pay the difference in cost, while the saving in traction would be from fifty to eighty per cent.

"These great highways will connect all the large cities, and will be crowded with vehicles of kinds now seen only in exhibitions or on trial trips. One need not look far into the future to see horses superseded for all road uses except pleasure driving, and largely for that. In the race for automobile vehicles between Paris and Rouen a year ago last July, over a hundred vehicles of different descriptions were entered. Those driven by electricity were barred for the want of facilities for recharging. In the next race these vehicles will be provided for, and with the steady diminution in weight required for storage batteries they will undoubtedly be a favorite class.

"The recent extended development of cheaper water power, together with the successful transmission of power by electricity, will furnish an abundant supply of motive power for such vehicles on all our great highways at a cost far below that of animal power.

"The city of Augusta, Georgia, furnishes water power at the rate of $5.50 per horse-power per annum, and makes money thereby. This is at the rate of 1¾ cents per day. Supposing this to be doubled for transmutation, and doubled again for transmission, and doubled yet again for profit, it would still furnish power on draft along the public roads for $1 per week per horse-power.

"One of the latest of the electrical carriages for two persons weighs but little over a ton, including passengers and battery. One horse-power will move this vehicle over a good stone road at fifteen miles per hour, or a thousand miles in a week, by daylight. This gives a journey of a thousand miles for two persons for $1, or about one-fortieth the cost of railway travel, not counting wear and tear of vehicle or battery."

A GREAT ROAD OF AMERICA.

In conclusion, Mr. President and Gentlemen, I may venture, without danger to public interests, to quote to you a few paragraphs from the unpublished "Year-book of the Department of Agriculture" upon the subject of object-lesson roads, and especially upon interstate and national roads.

"INTERSTATE OBJECT-LESSON ROADS.

"It is the intention of many States besides Massachusetts, either by connecting their detached sample roads or by laying down long lines to be built as a whole, to establish upon the principal routes of travel State roads, which shall be object-lessons on a large scale. The Legislature of New York has frequently had under consideration the subject of a network of roads connecting all of the county seats by north and south and by east and west lines. The same or similar plans have been proposed in Pennsylvania, Maryland, and California. Other States have proposed to limit these object-lessons to a single road running lengthwise of the State or to two lines crossing each other at the capital. Should these plans be put into execution, it will be very important that these roads in the different States should be made to connect at the State lines, and thus form interstate roads.

"NATIONAL OBJECT-LESSON ROADS.

"It would greatly increase the value of these interstate roads and stimulate a general public interest in road-building if some of these lines could be so connected or combined as to form, in a measure, a national system, such as was planned and partly built by the Government of the United States in the early days of this century. The most effective lines that could be adopted for this purpose would be an Atlantic Coast line and a Pacific Coast line joined by a continental highway extending from Washington to San Francisco. The greater part of the Atlantic Coast line already exists in a more or less passable condition. A Pacific Coast line, 750 lines in length in California, has been mapped out by the Highway Commission of that State. That portion of the continental line between St. Louis and Kansas City is already located as the first great State highway of Missouri. The remainder of the total of 5000 miles will be on lines naturally connecting great cities. Such a road as this, to be built by the several States within their own borders, and by the Government through its lands and reservations, would be an invaluable lesson not only as to the direct benefits of road improvement and the methods of accomplishing it, but as to the enhancement in value of property along its lines. In many States it would doubtless be built on the assessment plan, distributing the cost over many years, but ultimately placing it upon the adjoining and neighboring property specially benefited. The benefits of a national highway worthy of the name would extend for miles on either side of it, and would greatly exceed the cost of the road.

"The lines indicated would traverse the whole or portions of two-thirds of the States, and their construction would naturally be followed by that of parallel lines, making a complete national system including all of the States of this great Union."

DISCUSSION.

THE PRESIDENT.—This presentation of the road question is certainly very instructive. There is no doubt that the world knows how to build better roads, and I should infer from what General Stone has told us that the Department he represents is engaged in a work largely educational, and intended to show as object-lessons the economic value of better roads. It seems to me that the roads of to-day, away from our larger centers of civilization, are not any better than the roads which existed forty to fifty years ago. Here and there individual enterprise has built better roads; we have abundant evidence of it in our suburbs. I trust we have with us those who can contribute to the very interesting subject which has been presented this evening. We have present Mr. Budd, Commissioner of Roads of New Jersey, and I am sure the Club would be pleased to hear what he could tell us as to his experience in New Jersey and elsewhere.

H. I. BUDD.—I am not accustomed to public speaking, and not sure that I can tell what I do know. We have, perhaps, in our State a novel method of building roads. We have inaugurated the plan which other States are trying to imitate, and are, in a measure, following. New Jersey is located between two large States, perhaps one of the most favored locations in the United States, and its soil is used largely for the growing of vegetables which require transportation. We have been forced to cart that material over roads to the markets, and the cost of this cartage amounted to more than bringing produce from Chicago to the Eastern cities. The cost of transportation over even the short distances that intervene between producing points sometimes equaled the value of the products, and made the production of the vegetables and fruits of doubtful profit. A few years ago the farmers began to agitate, in their Granges, Farmers' Clubs, etc., the building of improved highways, and, as General Stone says, they soon found their local building would not amount to anything. When built in one township, others would not build, and the chain would be incomplete. Then they appealed, through their State Board of Agriculture, to the Legislature, and after hard fighting succeeded in getting an appropriation of $20,000. Such was the opposition to this, that they did not use that money. Next year they succeeded in getting $25,000, and that was only partly used. Wherever they undertook to use it the farmers and freeholders kept the expenditure down, so it was found necessary to introduce a mandamus clause compelling acceptance of this bounty of the State; that mandamus clause has been the salvation of road-building in our State. As soon as a road was built in a county and the farmers saw the benefit of it they were tumbling over one another to get roads; and now in those counties they are most eager to have the roads, and are willing to submit to the extra taxes. In one county in which the freeholders had to be mandamused to accept the provisions of the law about twenty-five miles of road have been built and about 125 miles more applied for. One of my sources of annoyance is listening to the farmers advocating new roads. The plan of building in our State requires the initial effort to come from the farmers living along the highway. They petition, agreeing to supply ten per cent. of the road, and the State agrees to supply one-third. Specifications are sent to me as Commissioner for approval, and, if obtained, they get the appropriation, and the balance comes from the county. For several years there were only four or five counties that accepted that provision. Now there are fifteen, and the whole number of counties—twenty-one—will probably be in it in a very short time. The appropriation of the State has been $100,000 for several years, which makes the total amount spent in the State $350,000 each year. There will probably be soon an appeal to increase the appropriation to $300,000, which means spending $1,000,000 a year in our State for public roads. It has been my aim in improving these roads to get as many line roads as possible. We are trying to get leading roads from our great centers and lines through the State. In another year we will have a road completed from Atlantic City to Jersey City, and on out through the western border of the State. This will probably be the longest line of macadamized road in the country. The feeling against building through that barren waste has been very great, but the number of carriages and bicycles that use that road shows that it is a wise provision. I stayed in Egg Harbor City one afternoon, and within three hours 3000 bicycles came through on that road. You all know of Mr. Thompson of our county. He asked me one day how many bicycles came down through the ferry gates and passed over those roads, and I guessed 3000. He said there were 5000. In the upper portion of the State there are several counties that surround New York City, and into which a great deal of the wealth of that city comes, and though the New York people are such as do not stop at any kind of expense, they have succeeded in bonding two or three counties and building fifty or sixty miles of road each, and now those are being extended. There is no difficulty whatever with the road population in any of the counties where they are started. The feeling has grown into a spirit of enthusiasm, which, under the present appropriation, has to be more restrained than encouraged; for when once a farmer rides over a good road and takes his produce over it, he is one of the most disgruntled beings if he can not have that road always to go over. When we first started out the people were extravagant in engineering, and some would not have a road unless they could have the most expensive. We are now building roads that answer the purpose for about $3000 or $4000 per mile. Few roads cost more than $5000. We tried to confine them to a road eight to twelve inches in thickness and twelve feet wide. Many of the roads are built four inches in depth. These roads seem to wear very well, and we build them mostly of macadam. Telford is more expensive and requires closer watching to lay properly; you may not get an ordinary supervisor to give the proper direction. The macadam is the more mechanical, and the point is to get the right kind of material in the first place, and then the right kind of machinery to keep the road together. There are many points that enter into construction of which you all know, but road-building in New Jersey is an established system. The majority, if it see the way to get the money, will increase it largely. Our State is a little different from others. We have no State tax, and all the State appropriations for all kinds of institutions are paid out of the receipts from corporations. We do not tax the people at all, and all the road taxes come out of the same fund. Many of our counties have built these roads without expending a dollar for taxes.

THE PRESIDENT.—I see that General Huidekoper is with us, and he may contribute something for our information.

HENRY S. HUIDEKOPER.—I do not know that I can add anything to the information you have. I believe that convicts should do the work very largely. I remember ten or twelve years ago I asked Governor Beaver to recommend in his annual message that convicts be employed instead of being kept idle in the penitentiary, but he did not do it. I believe convicts could be directed properly and would be well employed, even if only in making some holes through the Allegheny Mountains; that would keep them busy for ten or twelve years.

MR. BUDD.—In our State there are two counties employing convict labor in quarrying stone, and the Legislature passed a law last year by which that stone is distributed for the building of roads. In Mercer County they put it on the road to the depth of two to four inches, and they have wonderfully improved the roads where they applied this stone.

WILLIAM J. ROSE.—I felt much honored by the receipt of an invitation to be present this evening. I do not know why General Stone suggested me in connection with this discussion particularly, unless it was that he wanted to convince me by so flattering an invitation that he bore no ill-will for the rough ride I gave him through Cumberland County a year or two ago. I am not a road-builder, and I have not, as the gentlemen present perhaps will be glad to learn, a single statistic with me. I would like to borrow the mandamus of our friend from New Jersey; I think we need it in Pennsylvania. I know we need it in Cumberland County. I come from that portion of the State in which the conditions perhaps are best described by likening them to those set forth in a document attached to the back of a man hanging from the limb of a tree in Arizona: "This man was a very bad man in some respects, and a durned sight worse in others." That is about our condition in Cumberland County. I have been very much interested in what I have heard here this evening, particularly the suggestion which General Stone holds out about the postal savings-bank method. One of the struggles of my life has been to learn how to hold myself up by my own suspenders, and if we can learn that that method can be carried out, I think it is a very valuable idea. We are doing all we can to further the work of the Department and to further this progressive idea. I am sorry I am not a road-builder—only a road advocate; and I have no statistics with me.

THE PRESIDENT.—It is evident that we know what to do, and what we should do; but we require to be educated up to the point of absolutely feeling our need. Whether the bicycle has been a great missionary in that direction or not I do not know. Mr. Budd refers to the projected road between Philadelphia and Atlantic City and the number of bicycles crossing the ferry. Though the bicyclists generally choose a path alongside the road, they have emphasized the need for better roads, and through their leagues have done much toward creating better roads.

J. W. TOWNSEND.—General Stone has interested me very much in the past on the steel side of the question, one which he has merely touched upon in his paper this evening. I was rather in hopes that he would have had some diagrams or blue prints to show what he proposes in the way of steel construction for roads. A road of this kind, I think, is something in which engineers would all be interested on the practical side of the question. Has General Stone anything of the kind with him?

GEN. STONE.—I have not, but I think I can make a model out of a piece of paper.

Mr. Townsend.—I am interested in providing steel for what General Stone proposes. The mere allusion he makes in his paper to steel construction might present to engineers practical difficulties which, I think, he has entirely overcome; and he can explain better than I can just how he has overcome them.

Gen. Stone.—I have been assisted, and perhaps influenced very largely, by the engineers of the Cambria Iron Co. I began about a year ago, when the present Administration came into power. The new Secretary of Agriculture is a very strong advocate of steel highways; he lives in a country where the roads are very bad and little material offering. He came to the conclusion that steel roads would be a good thing for that region. I was of the same impression, but never dared to say so. I immediately sent to the steel and iron companies asking them to consult on the question as to what would be the best thing to do in regard to steel roads. The Cambria Iron Co. took the most general interest in it, and we consulted, and they modified my idea somewhat, which was a rail of steel resting on a wooden stinger in this way [illustrating], taking what some of you as railroad engineers know as a longitudinal stringer, such as was used on the Northwestern Railroad for nearly fifty years. A longitudinal stringer has no cross-ties except rods to tie them together. [Here illustrating with a piece of cardboard.] That stringer has about eight inches level surface, and a three-inch flange which gathers and holds the ballast, so that to remove those stringers they have to blast the earth underneath or pry it up. The constant jar and binding upon that has packed the earth and stone under it until it is absolutely hard. The effect of a stringer like that is to distribute the weight until there is no tendency to sink. The Cambria Co. recommended a little bead on the outside of the rail. I proposed to make that on the inside to prevent the water running off. The bead on the inside is just as good to guide the wagon by as on the outside, and it would give the water a chance to run off freely. This bead is not bigger than my finger—½ of an inch thick, perhaps ¾ of an inch wide. It is only intended to guide the wagon on to the rail. In connection with that, the point on which I thought I was original was making a fish-plate that should have a ramp on either end of it, and a slab at each end to make a riser for getting on to this rail, making at every joint a remounting place on each side. I think yet that is a good thing, but I found somebody else had a patent on it. We can dispense with that as a joint, because the Cambria Co. proposes an interior joint bolted through the flanges and extending on to each rail, and bolted, not through the surface, but through the sides. With that resting on broken stone or gravel there need only be a trench just wide enough to carry it. It would be some expense to prepare for rolling these rails, and we have not yet been able to get orders enough to start in on them; but a turnpike company at Scranton is ready to lay down two to three miles of this road. They have there a rough traffic. They could make roads out of the sandstone of the hills, but it wears out as fast as they put it down. They will put down two to three miles of this, and then I hope to see a great many miles of it. Mr. Mellville, of Pittsburg, has been making experiments with it and is now building a small section of it, but had to give it up until spring. Mr. Mellville made some tests on a road of this kind. He makes it of angle iron and plate, but he has not come to the point of rolling rails for it. He has made careful experiments regarding traction on it, and finds that it is only 2½ pounds to the ton, or about one-third of the ordinary load for traction on railways. He had a wagon amounting to 2⅓ pounds to the ton, and it would pull to the weight of three pounds. I found, when coming to talk about this in the newspapers, other people were working on it in the United States. A gentleman named Bliss, an engineer in Alliance, told me he had such a piece of road, and asked me to come and see it. It was both cheap and efficient, apparently. It was simply two eight-inch channels about $\frac{5}{16}$ of an inch thick, or less than ¼ of an inch. The lightest kind of channel iron was used, and laid down in a soft spot in an Alliance road, without any support underneath except mud, and no ties even —not tied together at all. You could go to one end of the track and pick it up. He filled in the space between with gravel, and that piece of road has been there for two years, traveled by everything from bicycles to traction engines, and nothing has disturbed it. I found it, in a wet time, perfectly level, smooth, and straight. It gave me great confidence in that kind of road and in the rail that such as the Cambria Iron Co. can roll—a substantial structure resting on a good foundation, with very strong fish plates, that requires, upon the scale we would build at Scranton, about 100 tons per mile of single track, and at the present valuation it would be about $3500 a mile. I shall try very hard, if the Scranton Turnpike Company is not ready to go ahead, to get a small appropriation to assist the Cambria Iron Co. to lay a small section next summer. We may get about $3000 to make the test, and it will be of great interest to engineers.

THE PRESIDENT.—Would not riding along the side be dangerous?

GEN. STONE (in reply to various questions).—Mr. Mellville turns it up here to put a stone alongside and hold it up to the level. My idea is to have these joints at every end of the rail. In the Alliance case I did not find any sign of a rut, but it was a very short section—only 100 feet long. I propose to use two or three inches of gravel. In countries where there is only black mud it can be burned to clay; but it would pay to bring in gravel by rail rather than to burn clay. Burned clay makes a good material, and is much better for substructure than for surfacing. If there were traffic enough, I would put the tracks on each side of the center and leave them just far enough apart for teams to pass. There would have to be a little space of gravel outside of that, so that if the wagon got off, it would not go into the mud. It would take some material besides the steel, but the wear would be altogether on the steel itself, and it would not wear out.

THE PRESIDENT.—The factor General Stone refers to is about one pound moving 600 pounds. As I recall it, on good dirt roads the traction is about 1 in 30. This would be only one-twentieth of that. It seems to be a question as to how to get good roads. In the statement of General Stone as to the average load in several States, was that the net load, or did it include the vehicle carrying it? Is State aid given to our roads?

GEN. STONE.—The net load was referred to. State aid is not generally given. In New Jersey and Massachusetts it is. Massachusetts is building what may be called State roads, but one-quarter of the cost is charged to the counties.

California is furnishing the material by convict labor, which is an aid that does not cost the State anything. A great many States are preparing the way for State aid. No others are giving it except Connecticut and Rhode Island, which are doing a little, whereby the State gives a portion and the county a portion. This makes five States doing something in the way of State aid. New York will probably pass a law this year and Michigan has changed its constitution with a view to giving State aid. Minnesota and Wisconsin are changing their constitutions for the same purpose. It seems to be the generally accepted plan for improving the roads; the object, of course, being to find some plan by which the property outside of the farms can be reached to give help to the road-building.

THE PRESIDENT.—Is the old plan of working out poll tax still in vogue?

GEN. STONE.—It is in some States. It is optional in towns in New York State, and about twenty to thirty towns have adopted it. It is also optional in some towns in the West. The system prevails pretty generally yet.

MR. BUDD.—I have long been an advocate of steel roads, but I find that the need of a sample road is felt. I believe that if we had a sample road there would be no trouble in getting many more built. All the inventors have sent me plans of roads, and I have always said if you will build a sample road we will get more of them. I think that if the Cambria Iron Co. would build a mile of road in our State it would be followed by the building of a number of miles. The farmers, if they see a good thing, will quickly jump to it, but will not take hold of it until they have seen it. If any large company would undertake to build even half a mile in our State, I will give them every facility to do it, and stand part of the expense, too.

THOMAS G. JANVIER.—I have enjoyed the paper very much; also the remarks of Mr. Budd. I do not think it well to go into a lengthy discussion, for we have had it here once or twice. I would like to ask Mr. Budd what material is used and how the subgrade is prepared for the four-inch road.

MR. BUDD.—It is prepared by thoroughly grading and rolling. No matter what material, there is no objection to putting gravel in the bottom. It does not seem to make any difference what kind of earth lies under the gravel—it seldom yields; and if it does, a little rolling in the spring settles it. I would not advocate the building of them.

MR. JANVIER.—Do you not think a six-inch road pays better in the long run?

MR. BUDD.—I do, and do not advocate less than eight inches, but they will not build anything over six inches. In our part of the State the farmers are not satisfied unless they have a ten-inch road; but I have refused to sign any specifications for roads over eight inches, and we can build very nice roads at only a little more expense.

MR. JANVIER.—In a narrow road, say a ten-foot road, in the early spring, when frost is coming out of the ground and there are clay shoulders, is there any danger from rutting?

MR. BUDD.—No. The trouble is merely imaginary. We do not see much, in that the loaded teams are mostly going toward the cities, and there is but little trouble. We ought to make those shoulders twelve inches; then if water gets on, it produces no effect.

Mr. Janvier.—With heavy travel both ways, would it not rut on both sides?

Mr. Budd.—I think it would. As you approach the cities you want wider roads.

The President.—Is the right of way conceded to loaded teams?

Mr. Budd.—Always.

Gen. Stone.—On some of the earlier built roads the grass has grown up in the stone roads to within about eight or nine feet of the track, showing that there was no occasion for the full width. Moreover, the grass grows on the shoulders of those roads everywhere, and you have a heavy side to turn out upon ordinarily.

Mr. Budd.—We have that in a part of the tracks. I have seen grass very high,—good mowing grass,—with just a pathway between; that is, on a nine-foot to ten-foot road. One of the most substantial roads we had is still there, and stands the wear in every respect.

The President.—I think Mr. Franklin has urged very light roads. I think he is with us and may say a word on the subject.

Benj. Franklin.—I believe in an eight-inch macadam road and not in the use of clay on any stone road. I believe in macadamized roads in preference to telford. I am glad that Mr. Budd concurs with my views.

Mr. Budd (in answer to a question).—The cost of maintenance on a good road, costing $3000 to $4000 per mile, is according to the traffic. It wears from ½ to ¾ of an inch in the year, and it depends very much on the kind of material used. We aim to use only the very best of trap. Where the railroads and rivers run through trap regions we get material very readily. The wearing qualities of trap are well known.

Mr. Franklin.—I have seen some roads of which the cost of maintenance was very heavy, owing to the use of narrow tires; and I wish to ask whether steps have been taken in any of the States to regulate the relation of the widths of tires to the load. It is a mistake to put down an expensive road and have it cut to pieces with narrow tires.

Gen. Stone.—There is a strong effort in this direction; much has been accomplished by law and much voluntarily, especially in the Southern States. There are very few wagons shod with narrow tires. Nearly every State in the Union is working on a wide-tire law, and it is a difficult matter to find a schedule to establish as a principle. I have been discussing that matter lately with people interested in it, and have made the suggestion that the width of tire should be equal to the square of the diameter of the axle at the shoulder, so that a two-inch axle should have a four-inch tire, and so on. It is a schedule easily carried out. The usual practice has been to regulate the width of the tire by the proposed load of the wagon, but that is an uncertain thing and does not amount to anything. The method of enforcing this, I suggested, was this: that a tax be put on all wheels of new wagons that do not conform to that standard. The result would be that the wagon-makers would conform to that standard, and would become advocates of wide tires. That would give a rebate on taxation to every man changing to the standard, and would not put any direct tax on the farmers. It has not yet been put in the form of a bill, but perhaps will be in the course of a few days in several States.

MR. BUDD.—On the subject of wide tires, municipalities can, by paying a bounty,—so much on a tire,—get good results, and some of them have adopted the plan. Last winter New Jersey passed a bill making the width of tires 3½ to 4 inches, and a bounty was fixed—so much on a wheel—for every person adopting it. The Governor vetoed the bill. This year another bill has been introduced which permits a bounty of $1.50 on each wheel and $1 for the second, and a fine of fifty cents on each wheel if not adopted in two years, and a penalty on every wagon-maker in the State who brings a wagon in with tires under four inches. Those interested in good roads are determined to have a law of this kind. Our previous State government was not favorable to it, but the present one is. I think so long as our roads are not all improved, there should be a uniform width of tire —say four inches. It would be a proper plan to adopt unless the roads become universally improved, and that would make the track for the sandy roads and the clay roads the same. We might have different widths,—they are each making their own track,—but with a broad tire the friction is very light, and all experiments made with a four-inch tire show it to be the most economical.

THE METAL DOME OF THE CITY-HALL TOWER, PHILADELPHIA, PA.

BY FRANCIS SCHUMANN.

Read February 19, 1898.

The following is an abstract from the official report of the writer upon the construction of the dome of the tower, the design of the structure and the execution of the work having been under his charge, as civil engineer, under the direction of the Commissioners for the Erection of the New Public Buildings at Philadelphia.

Existing literature relating to structures of the kind in question is as yet meager and limited, and therefore the publication of matter that may tend toward further elucidation of the subject is desirable. With this object in view, the writer feels justified in presenting this paper.

As a preliminary, the writer would state that the architectural form of the dome, as erected, is in accordance with the design of the late John McArthur, Jr., who, as architect of the Public Buildings, furnished a drawing of the dome showing a half-external view with all the architectural features, and the other half a section indicating framing similar in design to that prepared by the writer for Mr. McArthur some years previous. This earlier design of a framing was for a dome slightly varying in form from that finally adopted. It was modified to meet the alterations, shown in Mr. McArthur's last and final drawing, and served as a basis for the scheme of the present framing.

The imperative requirement of Mr. McArthur, repeatedly impressed upon the writer, that the work should be monumental in character, was rigidly complied with.

The work was begun early in 1890, and, exclusive of the bronze statuary and electroplating, was completed, ready for erection, by January, 1893.

The electroplating, however,—which amounts to some 120,000 square feet of surface, and included pieces weighing about 10,000 pounds each,—was necessarily slow and tedious, requiring nearly fifty months of actual time, working both day and night, and consequently delayed the final completion of the dome until the end of 1896. This period included the time during which the work was suspended from lack of funds, the actual time consumed being five and a half years.

An idea of the magnitude of the statuary work is gained by contemplating the mass of plaster models for the various groups and pieces to be made in bronze, twenty-five four-horse loads being necessary to convey them to the foundry from the City Hall, where they were modeled and prepared.

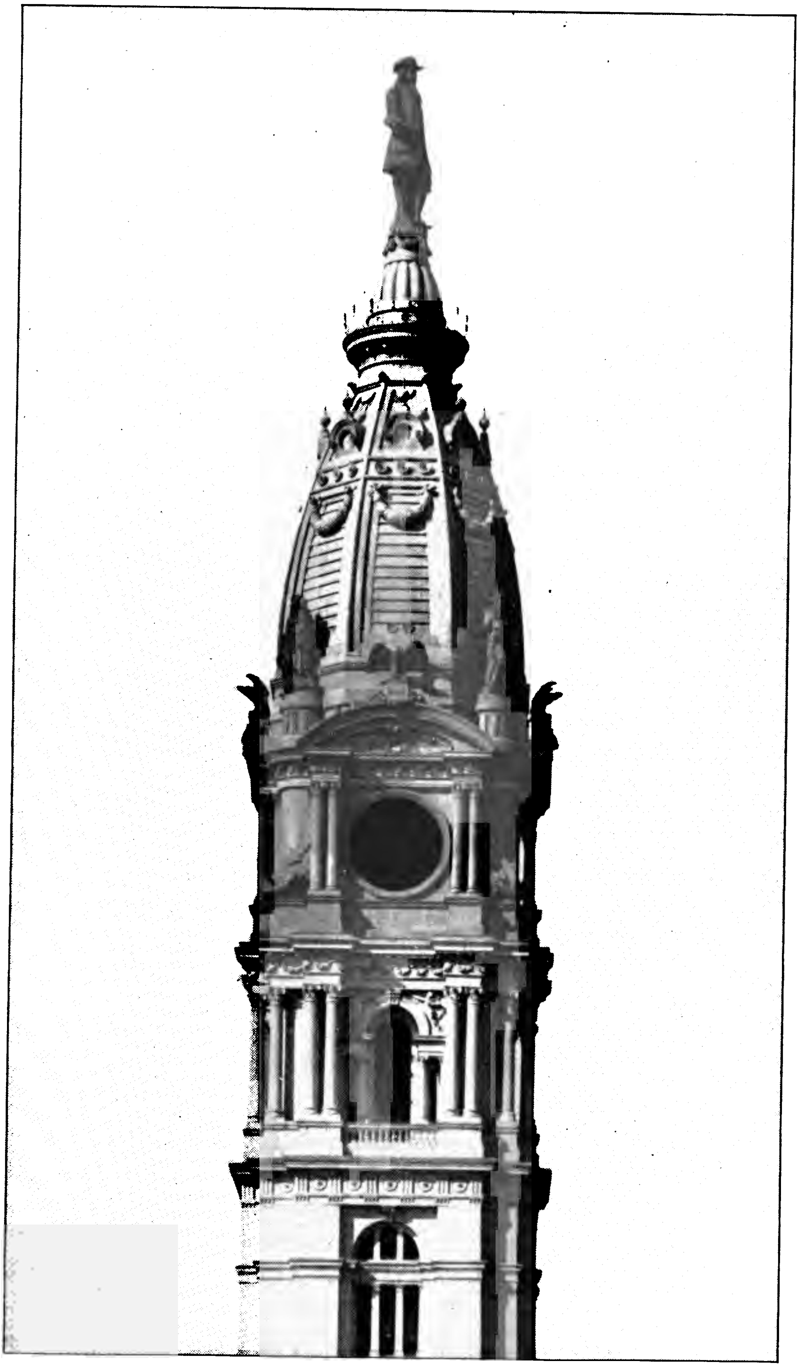
GENERAL DESCRIPTION OF THE TOWER.

The TOWER of the City Hall rises from the ground level of the courtyard side of the north front of the building. For a height of 337 feet 4½ inches above this level it is of brick faced with marble, forming a shaft averaging about 70 feet square in plan outside and about 45 feet inside measurement. The shaft is enriched architecturally by balconies, cornices, belt courses, columns, and pilasters; arched and square windows are located in each of the four sides at different altitudes.

Upon this shaft of masonry rests the metal dome, rising to an additional height, including the top of the Penn statue, of 210 feet 9⅜ inches, making a total height of 548 feet 1⅞ inches. The total estimated weight of the tower, extending from 15 feet below the ground line to the top of the concrete foundations, is 62,768 tons. The bed of concrete, 8½ feet thick, covers an area of 7150 square feet and weighs about 4000 tons additional. To a height of 90 feet the shaft is attached to and forms part of the north wing of the building, of which the lower portion of the tower virtually forms a part, the foundations and stonework having been built simultaneously and bonded together.

The lower portion of the dome, to a height of about 60 feet, forms the clock story. It is square in plan, each side being enriched with entablatures, segmental pediments, columns, pilasters, and plinths, and molded and enriched openings for the clock dial, 23 feet in diameter; the center of each clock dial is 361 feet 3¼ inches above the ground level.

From the clock story rises the pyramidal part, octagonal in plan, with sides slightly curved, paneled, and enriched with cornices,



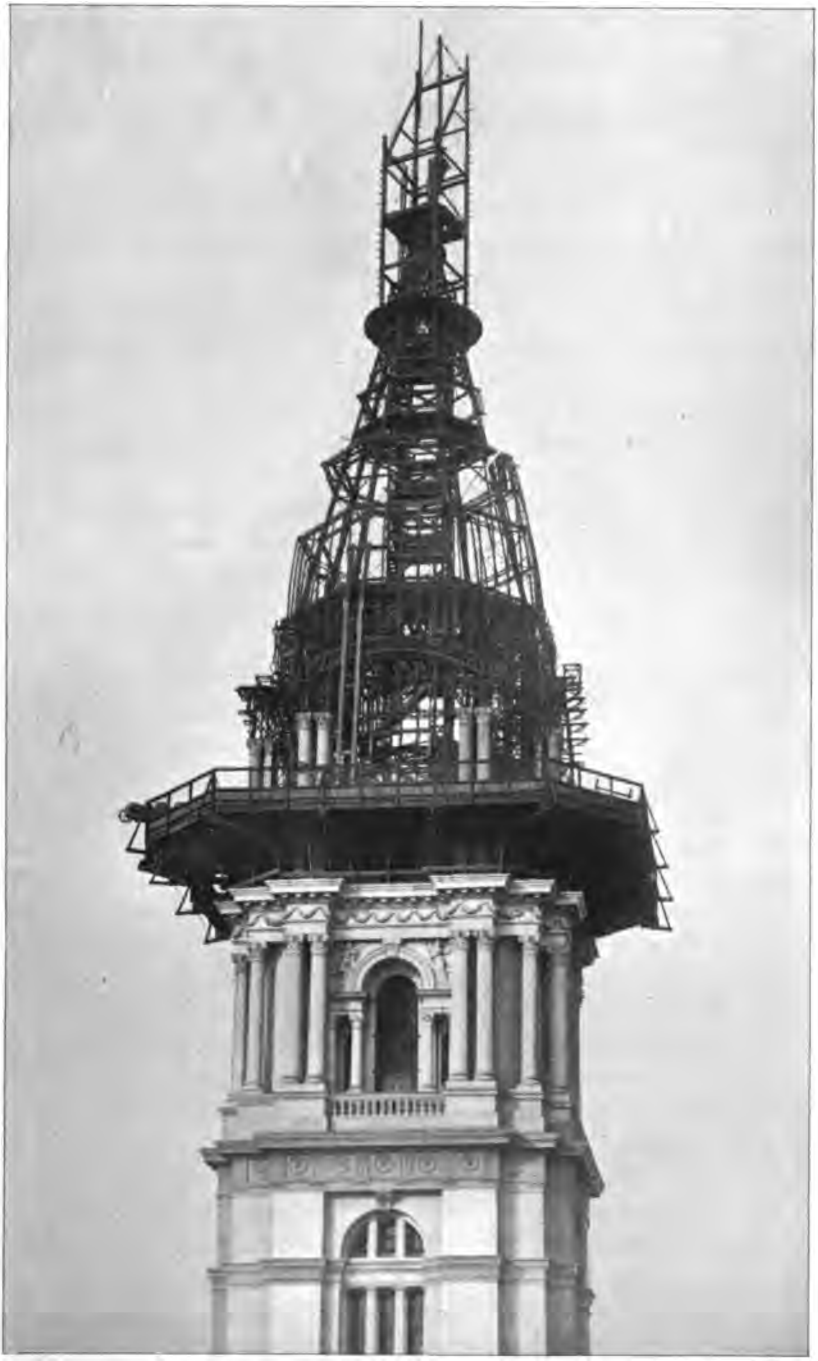
View of Tower from the East.

dormers, festoons, and ribs at each corner of the polygon. At a height of 144 feet 11¼ inches above the masonry, or 482 feet 3¾ inches above the ground level, is the floor of the balcony, which will be the highest point accessible to the general public by means of stairs and elevators. From this balcony floor level to the top of the Penn statue is 65 feet 10⅛ inches. By means of ladders through the tree stump, which forms a support for the statue, thence into the body of the figure, and then further by ladders, the glazed manhole plate in the crown of Penn's hat is reached. This, upon removal, gives access to the top of the statue.

Bronze eagles, resting on dies, surmount each of the four pediments, while allegorical groups in bronze, representing four epochs in the early history of Pennsylvania, are supported on dies formed between the square of the clock story and the sides of the octagonal pyramid. The bases of these groups are 394 feet above the street level, the principal figures of the four groups being 24 feet high. The envelope, or shell of the dome, is electroplated cast-iron, with the exception of the louvered panels of the pyramidal part, which are composed of sheet steel, also plated.

The framing or structural part of the dome is of wrought-iron, except certain portions of the apex-cap, which are of steel. The general outline is, first, an octagonal prism, to the height of the clock story, the remainder being an octagonal pyramid, ending with the apex-cap which supports the Penn statue. The octagon is formed by meridional columns or chords at the corners of the polygon. These columns are supported on four box girders placed diagonally across the corners on the top of the masonry, bedded on cast-iron plates, about one-third of the length of a girder, and placed at the middle of each. This brings the superimposed weight of the dome, through the columns, to the clear ends of the girders, which act as cantilevers, thence to the solid portions of the masonry, thus clearing the window openings located at the sides below the ends of the girders. These girders are bolted to the masonry by two 3-inch diameter anchor rods to each girder. These rods extend down through grooves in the brick work 70 feet to anchor plates imbedded in the wall.

The bracing between the respective columns or chords consists of horizontal struts, dividing the dome into ten tiers of bays or panels, each panel being intersected by diagonal tie-rods; in the three upper



View of Tower; Part of Framing in Place; Main Platform and Scaffolding for Erecting Penn Statue; Right Leg in Place.

tiers of panels the diagonals are arranged to resist both tension and compression.

The upper ends of the columns, where they converge, are joined by an apex-cap, which is an octagonal tube formed of steel plates and angles, stiffened with gussets and circular top-plates, upon and to which the Penn statue is bolted.

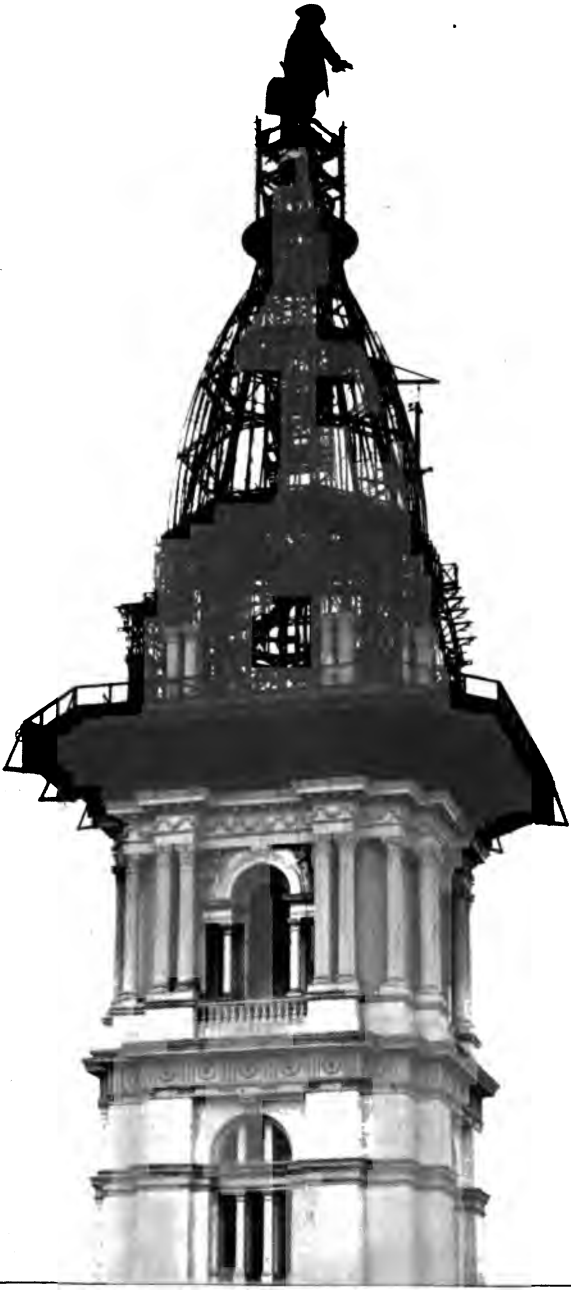
To maintain the form in plan, ties are provided at each horizontal plane, between the panels, and connecting each alternate column or chord.

The four groups of 24-foot statues are each supported by a framed pier, square in plan, and composed of vertical angles at corners braced with diagonals and struts. They extend from the bases of the statues down to the top of the masonry, and are secured to the main body of the framework of the dome by means of horizontal latticed girders that extend around the columns in the form of octagonal rings, arranged also to support light upright latticed frames, which carry the main cornice of the clock story by means of cast-iron brackets bolted to them, and having an outline approaching the profile of the cornice.

The segmental pediments are carried by arched lattice girders, the ends of which are supported by the enriched cast-iron columns which rest upon the masonry, thus relieving the framework of the prism of the weight of the shell of such portions of the pediment and cornice as are attached to the arched girders.

Octagonal rings, composed of light lattice girders, also surround the pyramidal part at various points, and form the supports for the curved jack-rafters, which carry the shell by means of cast-iron brackets. The rings are fastened to wrought-iron brackets which project from the chords or columns of the pyramidal frame.

The dome is subdivided by floors as follows: The first floor, at a level with the top of the masonry, is composed of girders and beams filled in with brick arches leveled with concrete and covered with a layer of asphalt. This floor was in place previous to the erection of the dome. The second or cantilever floor is at the intersection of the prism and pyramid. Cantilever trusses spring from the eight chords or columns, converging toward an octagonal ring, which forms an opening for the passage of a contemplated stair and elevator. Rolled beams extend between the cantilever trusses, upon which it is proposed to lay $\frac{1}{4}$-inch thick plates of steel covered with



View of Tower; Part of Framing in Place; Main Platform and Penn Statue.

$\frac{3}{8}$-inch thick rubber sheets as a flooring. The third floor is immediately below the circular dormer windows; it is supported on framed brackets springing from the chords, the floor otherwise being similar to the second. The fourth or balcony floor is a few inches above the balcony gallery, to which it forms the approach; in construction, this floor is similar to the last. All floors are alike as to the opening for stair and elevator. The third and fourth floors are provided with the rolled plates, but not the rubber. The floor of the balcony gallery is of "Tarezzo," a layer of cement in which small cubes of marble are imbedded, the surface finally ground and polished smooth.

The cantilever and balcony floors are lighted by eight circular windows; both sets of windows are arranged to open for the purpose of ventilation.

The shell, which is supported by means of divers forms of cast-iron brackets bolted to the secondary framework, is, as before stated, of cast-iron, generally $\frac{1}{4}$ of an inch thick and fastened together, and to the brackets, by means of $\frac{3}{16}$- and $\frac{3}{8}$-inch diameter brass machine screws. All joints are covered by either cast or wrought straps or welts on the inside, cast-iron being used in all profiles of moldings and at corners.

Between the straps or welts and at the joint of the respective plates or members of shell strips of asbestos steam-packing cloth, equal to the width of welts,—four inches,—and covered with a preparation of linseed oil and white lead, were placed; the machine screw then passed through and nuts tightened, thus compressing the packing and making a close, watertight joint. Expansion and contraction were provided for by utilizing such of the architectural features as would permit their use as an elbow which would deflect with the variations of length of the piece to which it would be perpendicular. In other cases the ends of members were arranged loosely, with necessary drips and raised edges to shed the water; this latter method was applied to the steel sheets forming the louvered panels in the sides of the pyramid.

Great care was exercised to complete the fitting of the shell during the preliminary erection at the works, so that in no case would the electroplated surface be disturbed when finally erected.

GENERAL DIMENSIONS AND WEIGHT.

The principal dimensions of the framework of the dome are as follows:

	Feet.	Inches.
From top of marble cornice to the top of the box girders that support the columns,	4	9⅝
From top of box girders to intersection of prism and pyramid,	64	1½
From intersection of prism and pyramid to top of chords of pyramid, being the height of the pyramidal portion,	99	11⅛
From top of columns, or chords, to top of apex-cap plate, including the apex-cap,	4	4¾
Total height from top of marble cornice to top of apex-cap plate,	173	3
Thickness of the bronze base-plate which rests upon the apex-cap plate and supports the Penn statue,		6⅜
In plan the dimensions of the prism are of an octagon in a circumscribed circle, through the centers of the chords having a radius of,	26	6¾
While that of the top of the pyramid chords, where the apex-cap joins, is,	2	5¼

The actual weights of the metal in the structure, as per records in shipping book, and their distribution, is as follows:

	Tons.
Total wrought-iron and steel,	366.8
Total cast-iron,	574.0
Total bronze in statues,	80.1
Grand total,	1020.9

Of these weights there rests directly upon the granite blocks at the top of the masonry and not affecting the primary framing:

	Tons.	Tons.
Cast-iron in shell,	375.8	
Four cast-iron bed-plates under box girders,	5.4	
Four box girders supporting chords,	37.4	
Four vertical lattice piers, including cast-iron base-plates and 24-foot bronze statues,	78.5	
Three tiers of octagonal rings and lattice girders (½),	6.8	
Cornice verticals, lattice (½),	8.1	
Four arched girders for pediments, including bronze eagles,	35.4	
Total,		547.4
Weight carried by primary framing, wrought-iron and steel,	259.0	
Cast-iron in shell,	187.7	
William Penn statue,	26.8	
Total,		473.5
Grand total, as before,		1020.9

The bronze statues weigh in detail:

	Tons.
William Penn,	26.79
Swedish man,	8.65
Swedish woman,	9.74
Indian chief,	11.88
Indian squaw,	9.77
Four eagles,	13.24
Total bronze,	80.07

GENERAL FORM OF THE STRUCTURAL MEMBERS.

The chords or columns are rectangular in section, composed of four angles, two web-plates, and two sides latticed.

The ring-struts between the chords of the prism are box-shaped, consisting of four angles with lattice webs on sides, while those for the pyramidal portion have four angles with a single lattice web; the two upper tiers of struts have solid web-plates instead of lattices.

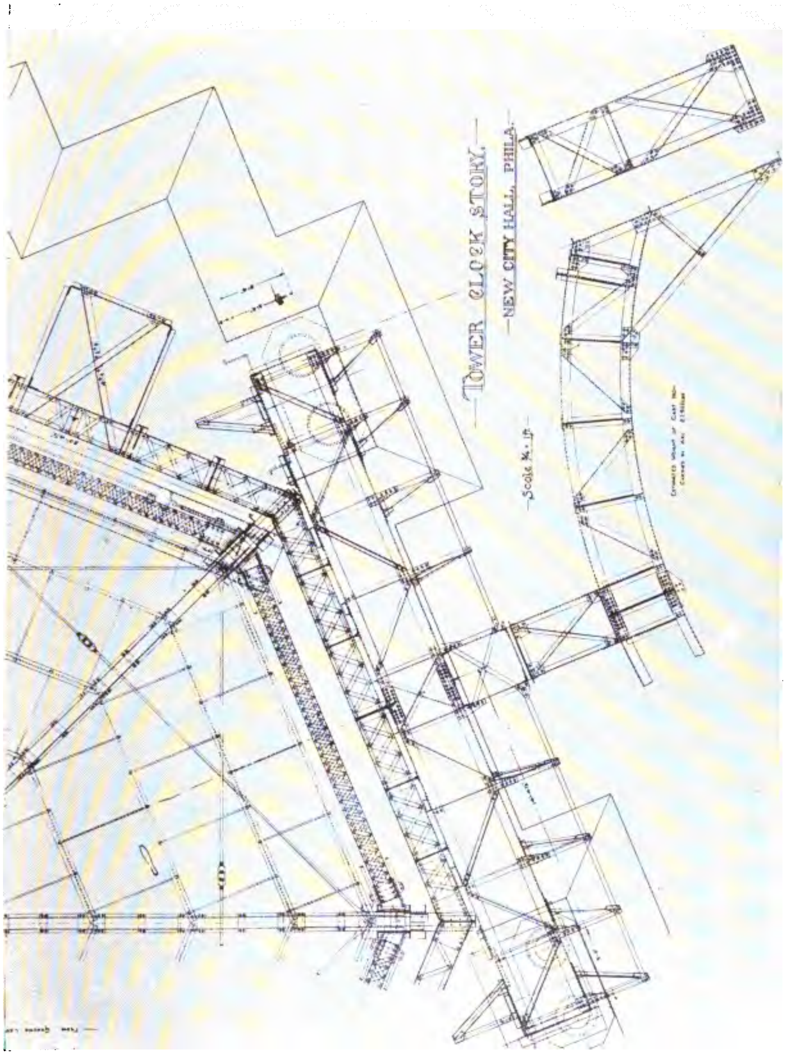
All diagonals are square in section, with welded loops, and are provided with turnbuckles or clevises. All pins are of steel, turned, and have a clearance of $\frac{1}{64}$ of an inch in their holes.

The trusses of the cantilever floor, which spring from the chords of the prism, are pin-connected and composed of channels with flange- or cover-plates; the struts are made of four angles and one web-plate; the tension members are square bars with welded loops but no turnbuckles.

The lattice girders of the prism, which carry the vertical lattice frames of the cornice, are box-shaped, made of four angles latticed together on the four sides; the lattice frames are also of four angles with a central lattice web.

The lattice girders that support the jack-rafters of the pyramid consist of a lattice girder with two angles, one at top and one at bottom, latticed together. Longitudinally with the middle of the web, which is vertical, is a third angle, to which is connected another lattice girder, with web in a horizontal position, the inner flange, consisting of two angles, having strap-braces at various points connecting with the angles of the vertical web girder, the whole forming a T-girder capable of resisting both vertical and horizontal forces.

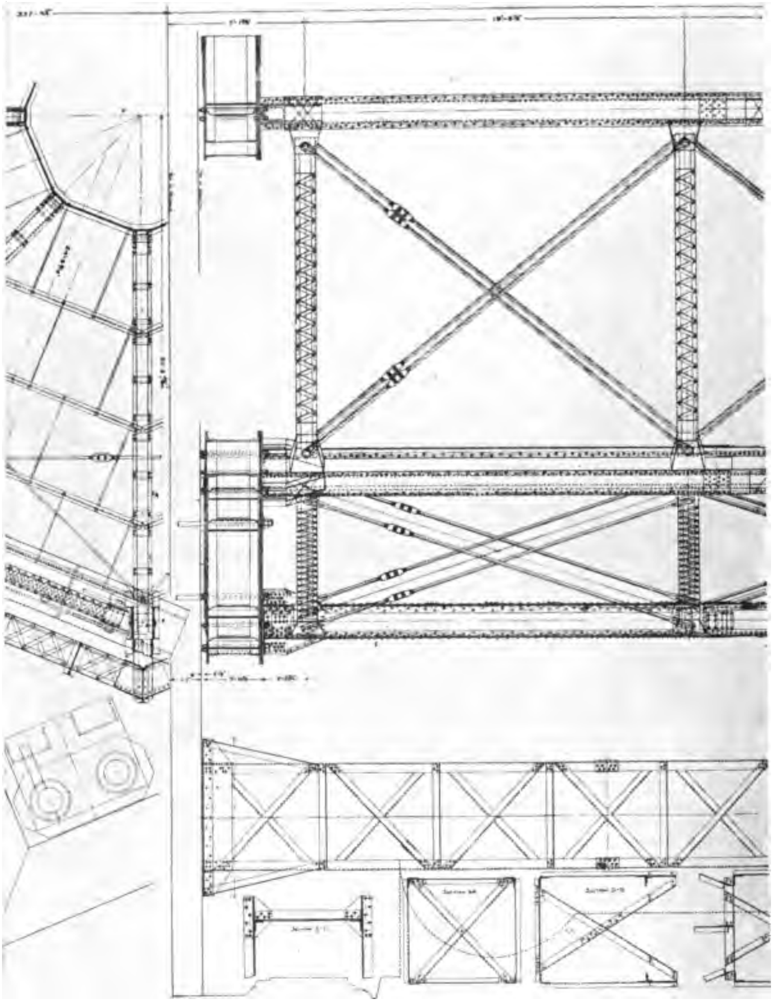
The brackets that spring from the chords of the prism for supporting the lattice girders are gusset-plates stiffened with angles, while those of the pyramid are horizontal angles and angle-braces.



General Drawing, Division I.

The jack-rafters are each made of two angles curved, placed back to back, and parted by washers to obtain space for connections at ends to lattice girders.

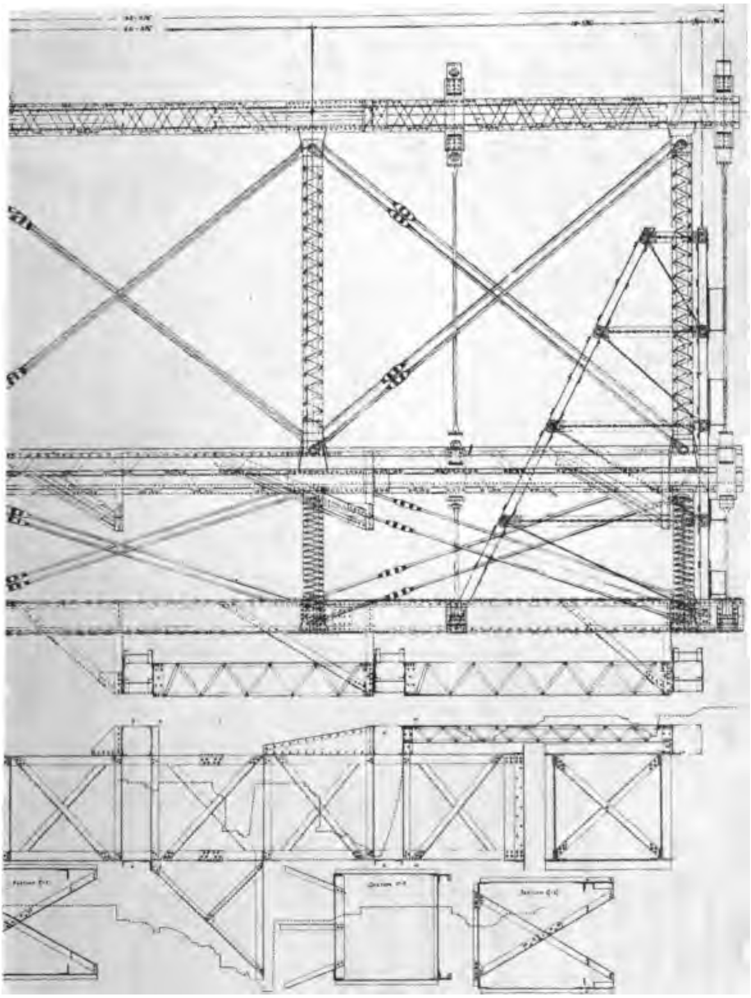
As before mentioned, the primary framing is relieved of all weight possible, and hence the ornamental cast-iron columns and pilasters of the clock story have been utilized to support the arched pediments and adjacent cornice, and the four groups of 24-foot bronze statues are carried by independent framing. The shell of the prism is likewise



General Drawing, Division II.

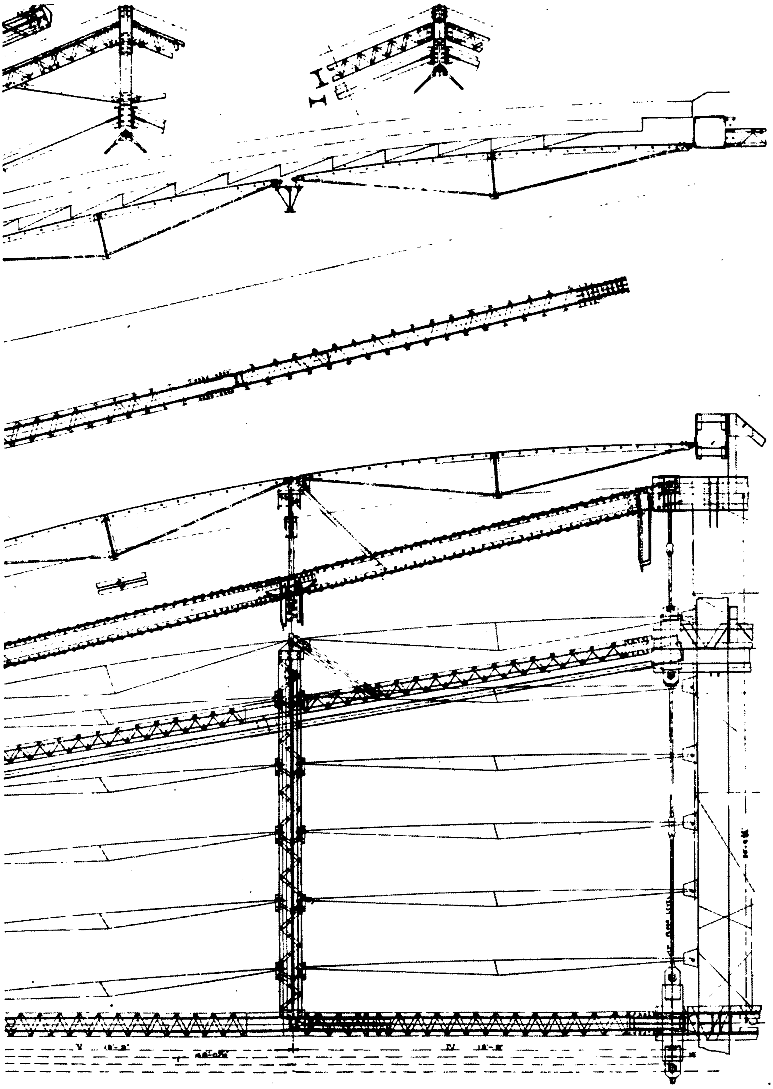
supported directly upon the granite base-blocks that form the foundation for the dome.

The apex-cap is of steel, in the form of an octagonal tube 5 feet and ¾ of an inch across and 4 feet 3¾ inches high, with the eight corners flattened to receive angle-iron stiffeners; the top of the tube is formed by a circular cover-plate, ⅝ of an inch thick and 8 feet 11¼ inches



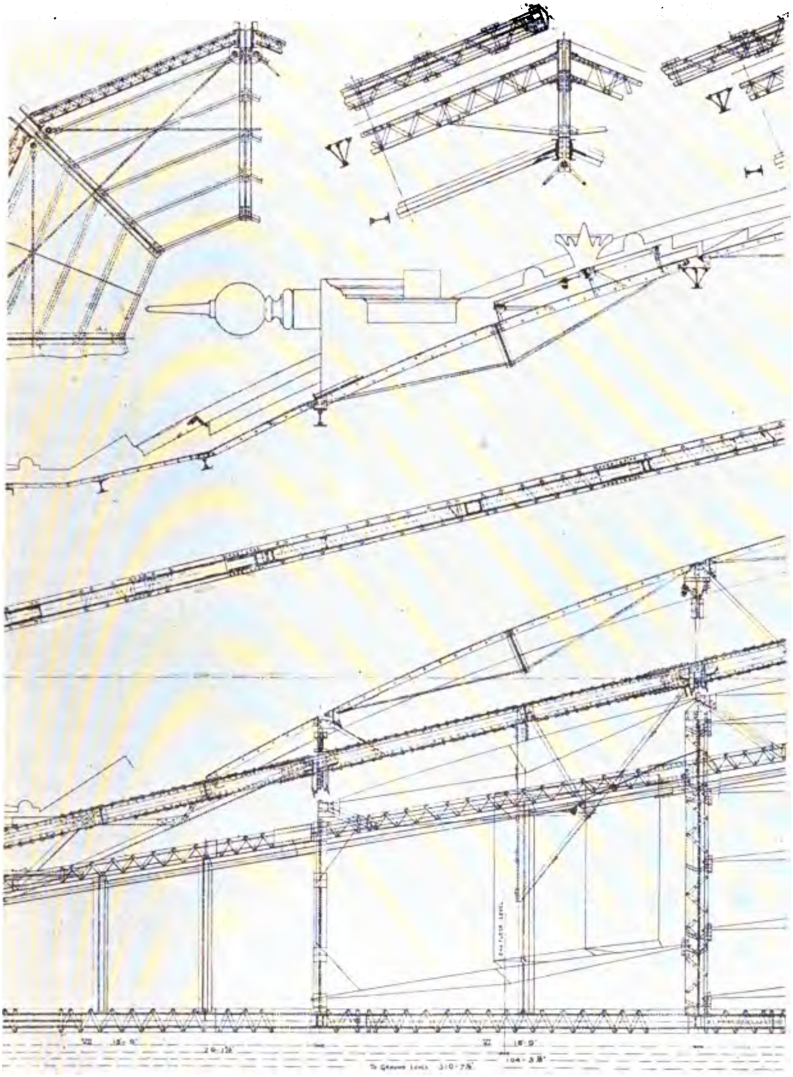
General Drawing, Division III.

diameter. The tube is formed of bent plates, $\frac{3}{8}$ of an inch thick. Both tube and circular plate are in halves, connected by fish-plates.

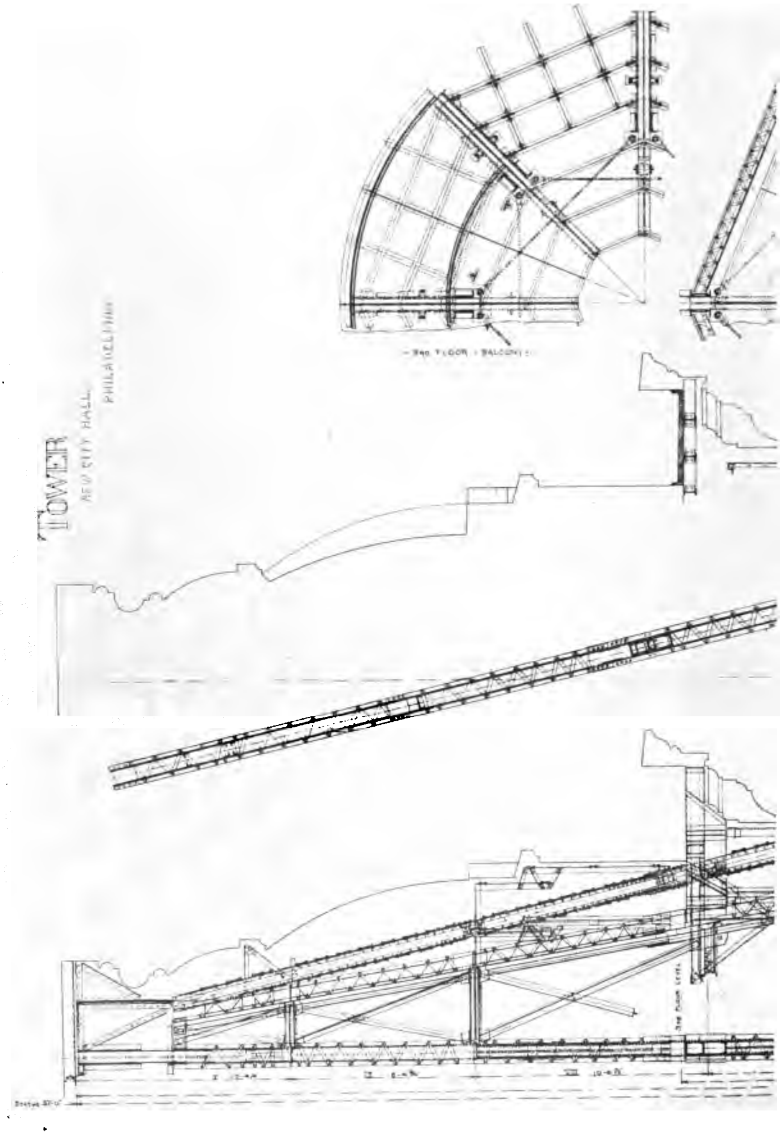


General Drawing, Division IV.

Both upper and lower edges of the tube are stiffened by bent angles riveted to the inside. The top plate, which is riveted to the angle of the tube, is also supported by sixteen double gusset-brackets on the outside and six on the inside of the tube, all riveted and bolted together to form a homogeneous body. The gusset-plates on the outside have holes to receive pins for eye-bolts for securing the bronze



General Drawing, Division V.



General Drawing, Division VI.

base-plate of the Penn statue; two manholes are provided in the cover-plate.

The connection of the apex-cap and top of pyramid chords is by bolts through lower angles of tube and U-plates between chords; besides this, the angles that connect the gussets with the tube extend down below the tube between the webs of the chords, to which they are bolted; in addition to this, eight heavy T-bars connect the tube with cover-plates on the chords. The joint between the apex-cap and ends of chords received special attention and revision, and was so designed as to obtain a high factor of safety.

All principal connections or joints that could not be riveted in the shops were arranged to be fastened by turned conical bolts, fitting holes reamed after the members were in position at the site.

WILLIAM PENN STATUE.—The bronze base-plate supporting the statue rests directly upon the cover-plate of the apex-cap; it is 9 feet in diameter and 6⅜ inches high, cast in halves, and formed of radial and annular ribs, 1 inch thick, cast on the upper plate, which is 1¼ inches thick; the halves are bolted together through two ribs that form the joint, and the whole is bolted to the apex-cap by eight 1½-inch square steel eye-bolts with 2¼-inch diameter nuts; these eye-bolts are held by the steel pins in the brackets of the apex-cap and placed in a circle. Two of these bolts enter the feet of the statue. Besides the eye-bolts, each foot is bolted to the base-plate by four 2-inch diameter bolts, two of steel and two of bronze.

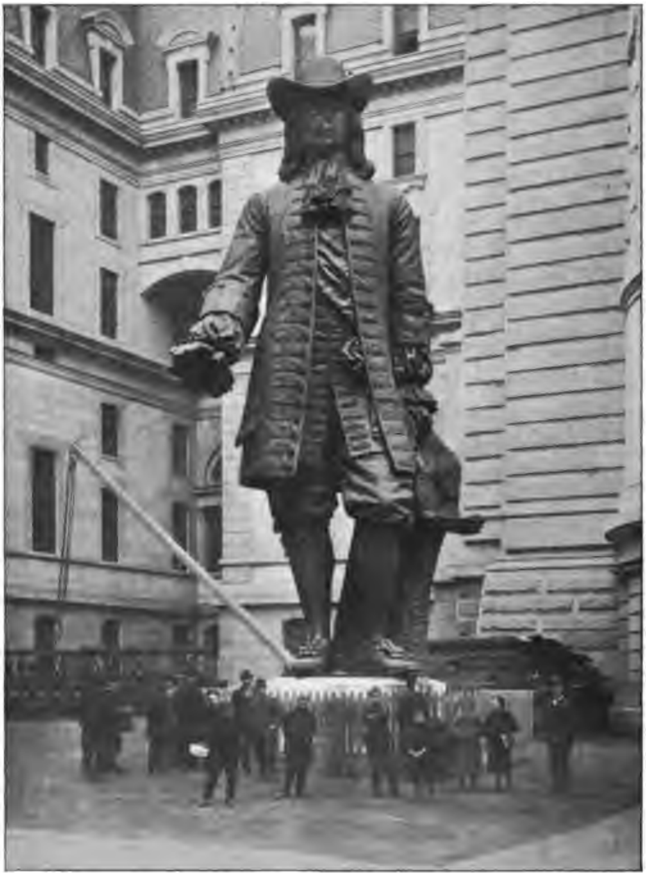
The tree stump, forming a part of the statue, is bolted to the base-plate by thirty-six 1-inch diameter bronze bolts, while the parts that form the figure are bolted together through flanges, as also to the stump, thus forming one united mass—the connection between stump and figure being at the left hand, skirt of coat, and thigh of body to the upper portion of the stump with bolts.

The thickness of the metal of statue varies from ¼ of an inch in upper parts to ¾ of an inch at the ankles and 1¼ inches for the soles of the feet. The stump averages ⅜ of an inch in thickness, and all flanges for joining the parts were ⅝ of an inch thick and about 3 inches wide.

The base-plate is provided with two manholes—one to the outside and the other to the interior of the stump. These are furnished with watertight manhole covers. Another manhole is in the crown of

Penn's hat, the cover-plate of which is glazed to light the interior of the figure. No internal braces were found necessary in any of the statues.

The four groups of 24 feet high statues at the base of the pyramid are supported on cast-iron base-plates bolted to the upper members of the framework below. The plates are covered by ⅜-inch thick bronze plate, upon which the statues rest, being bolted to the cast-iron base-plate through the feet and other available members of the statues.



PENN STATUE IN COURTYARD OF CITY HALL; HEIGHT, 37 FEET 6⅜ INCHES; WEIGHT, 53,580 POUNDS.

The alloys composing the statues were: For William Penn and the Indian chief, 90 parts copper, 10 of tin. All other statues were 88 parts copper, 10 of tin, and 2 of zinc.

Painting.—All structural parts were carefully cleaned of all rust and scale and painted with iron oxid and linseed oil. All surfaces in contact received one coat previous to assembling, and all the work one coat at the shop and two coats after erection.

ELECTROPLATING.

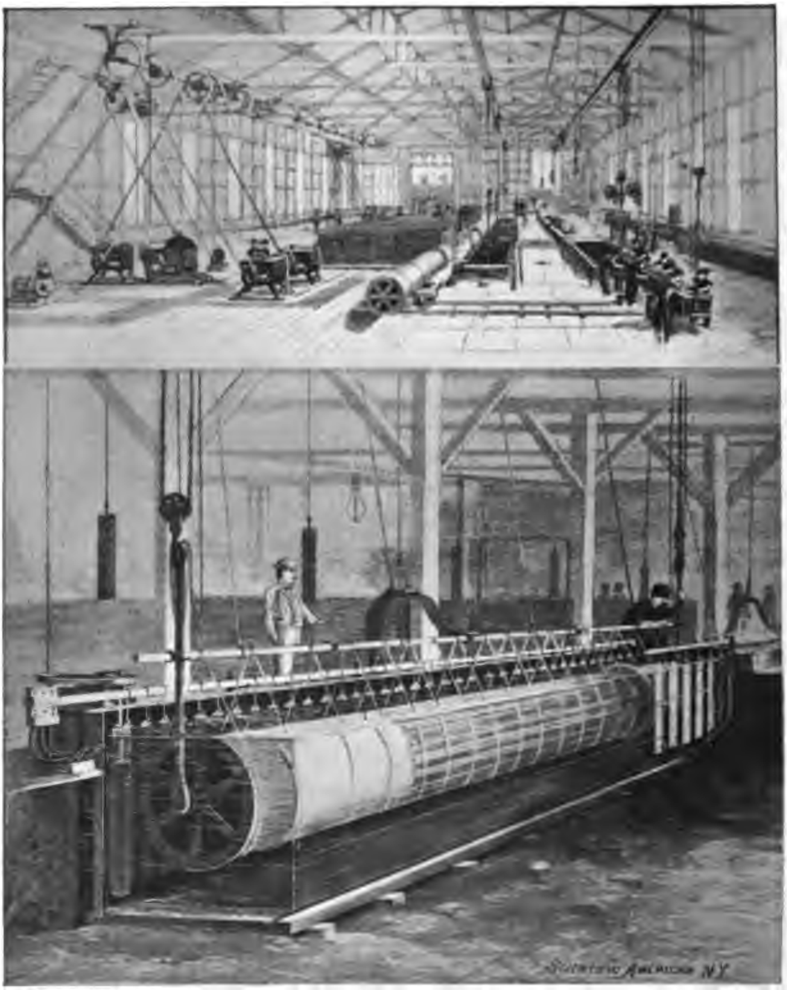
The electroplating of the shell of the tower was performed in a building especially erected for that purpose. It was 60 feet wide by 120 feet long, of heavy framework of wood, one story high, sides and roof covered with corrugated iron. A row of timber posts, supporting the middle of the roof trusses, divided the floor area into two clear spaces. The north space contained two rows of pits, three in each row, made watertight by concrete and cement sides and bottoms. The pits were of dimensions to receive the plating tanks, and of such depths that the rims of the tanks were about 18 inches above the floor level, and of sufficient width and length to leave a space of 8 inches between the outside of the tanks and walls of pits. This space was kept full of water to a level with the surface of the liquid in the tank, and thus acted as a counterpoise to prevent both the bulging of the sides of the tanks as well as to prevent leakage, the hydrostatic pressure being the same on both inside and outside of the tanks.

Over the center of each row of pits, and attached to the under side of the roof trusses, was a track made of 10½-inch rolled beams, carrying three trolleys and chain-hoists, each of sufficient capacity to raise three tons. The trolleys were moved back and forth on the tracks by means of a system of ropes running over sheaves and leading to geared drums operated by hand cranks.

The tracks, which extended beyond the tanks, permitted the transportation of a piece to be plated, by means of the trolleys, from place to place as might be required, the raising and lowering being done with the chain-hoists.

At the end of the rows of tanks was located the cleaning floor, having a small tank supplied with running water.

The other or south space of the floor was occupied in part by a 75 horse-power boiler and 50 horse-power steam-engine, four dynamos, storage-room, and workbenches for marking, inspecting, and assembling the pieces for shipment.


SCIENTIFIC AMERICAN N.Y.

INTERIOR VIEW OF PLATING PLANT; ONE OF THE 1000-POUND COLUMNS IN THE BATH.

The first row of plating tanks were:

1. *Caustic-soda tank,* of plate-iron, 5 feet wide, 5 feet deep, and 31 feet long. The temperature of the solution was maintained at about

210° F. In this the articles were immersed from two to six hours, for the purpose of removing all grease or fatty substance. From this tank the piece was taken to the—

2. *Pickling tank,* made of wood, same dimensions as last, lead lined, and containing a ten per cent. solution of sulphuric acid, at a temperature of about 150°, the article being immersed from two to six hours to loosen or remove all rust, silica, or other matter, the cleaning being by scraping and rubbing with wire brushes, which was done at the cleaning floor, previous to treatment in the—

3. *Alkali-copper tank,* also of wood, and of same dimensions as the last. This bath was about 150° temperature, and was the first in which a deposit of copper or alloy of copper and tin was applied. The anodes were hung to 1¼-inch diameter brass conductor rods, supported on short brackets at both sides of the tank, while the cathode, or piece to be plated, was hung to a single 2-inch diameter brass conductor rod, suspended over the middle of the tank by means of ropes over sheaves overhead balanced with counter weights. The round conductor rods were connected to flat copper conductors from the dynamos by flexible copper wire strands, to permit shifting of the round rods. The time of plating was about twenty-four hours, under 4 volts and from 1000 to 2000 amperes.

From this tank the piece was taken to the second row of tanks, the first being the—

4. *Acid-copper tank,* similar in all respects to the last, except that it was lead lined and not heated, and that the conductor rods were respectively 2 and 2½ inches in diameter. At one end of the tank, in a corner, an agitator for effecting circulation of the liquid was located, consisting of an upright copper tube about 8 inches diameter, within which a small propeller wheel secured to a vertical spindle revolved, driven from the line of shafting. The anodes were of copper, and time of plating seventy-two hours, depositing about 14 ounces of copper to a square foot of surface. The voltage was 4 and amperage from 1000 to 2000. The next was—

5. *Aluminum tank,* of wood, 5 feet wide, 8 feet deep, and 31 feet long. This bath was heated to about 180° by means of steam-pipe coils lying at the bottom of the tank. The anodes were of aluminum alloyed with 15 per cent. of tin; conductors 1¼ and 2 inches diameter respectively, otherwise same as acid-copper tanks. Time of plating,

seventy-two hours; 4 volts, 2500 amperes. The resulting deposit of aluminum, 2½ ounces. The next and last treatment, that in the—

6. *Water tank*, also of wood, same dimensions as copper-acid tank, filled with clean water at about 210°, in which the article was thoroughly cleaned by immersion and stream from a hose applied repeatedly.

Eventually, to expedite the work, two more tanks were added—one acid-copper and the other aluminum. These were of plate-iron and were placed directly upon the floor in the south space near the dynamos; they were about 12 feet square and 4 feet deep; otherwise they were arranged like the larger tanks for the same purpose.

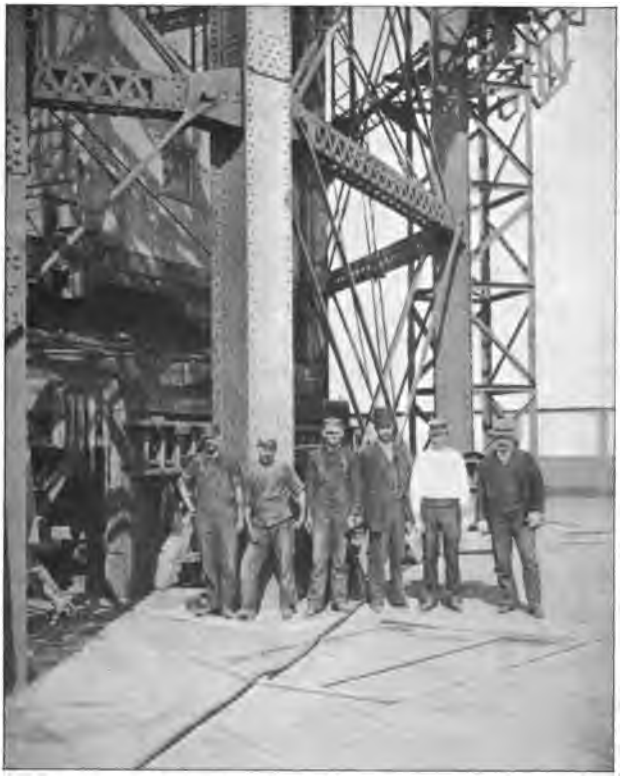
Before proceeding with the plating, the parts to be plated, after being completely fitted in place during the preliminary erection at the works, were, upon their reception in the plating department, carefully tagged with the number and location on a sheet of brass, wired to the respective part, to which it remained attached until ready to fix in place at the building.

Upon the completion of the treatment in the alkali tank, and previous to treatment in the acid-copper tank, the article was carefully examined and all pin-holes or other defects cleaned and filled with solder composed of tin and lead. Likewise, when the article had received its deposit of copper, it was again examined, the thick edges, which tended to form in the acid-copper tank, removed by filing, and, in the event of blisters having formed, they were cut out and the piece subjected to a second treatment for copper.

SCAFFOLDING AND ERECTION.

For the purpose of avoiding all damage to life and property during the erection of the work, and especially because the principal north entrance of the building passes through the base of the tower, and could not be closed without materially interfering with the traffic of the city, it was deemed imperative to provide a scaffolding that would not only be a basis for operations for the work above, but would also act as a shield for the protection of the public below.

For these purposes a scaffolding, in the form of a platform 105 feet across and with octagonal corners, was erected; its floor level was about 10 feet above the top of the masonry, or about 347 feet above the ground level. It consisted of 16 cantilever girders, composed of plates of iron bolted between heavy timbers 8 by 16 inches, thus forming flitch beams from 42 to 50 feet in length, projecting radially beyond the faces of the tower and supported near the outer edge of the walls, from which point braces extended up to the under side of the girder, both outward and inward. The inner ends of these girders were provided with cast-iron caps bolted to a cast-iron ring about 20 feet in diameter, which was anchored to the two main floors below by 32 iron rods; stanchions were also inserted between the inner ends of the girders and the floor below for sustaining the loads above.



On Main Platform, Showing Part of Prism Framing.

The outer edge of the scaffolding was guarded by a fence about 6 feet high, the lower half of which was covered with 1-inch tongue and grooved flooring, while the upper half was filled with ⅛-inch galvanized iron wire netting.

Spanning the spaces between and spiked to the radial girders 4 by 14-inch joists were placed, about 12 inches apart; on these, 2-inch planks were spiked, forming a rough flooring, upon which a thickness of heavy tarred paper was laid, and this again covered with 1¼-inch yellow pine tongue and grooved flooring as a finish. This floor was watertight, pitching slightly toward the middle of the tower, where drain-pipes were provided for taking off the water. The floor of the platform virtually formed a tight roof over the otherwise exposed interior of the tower.

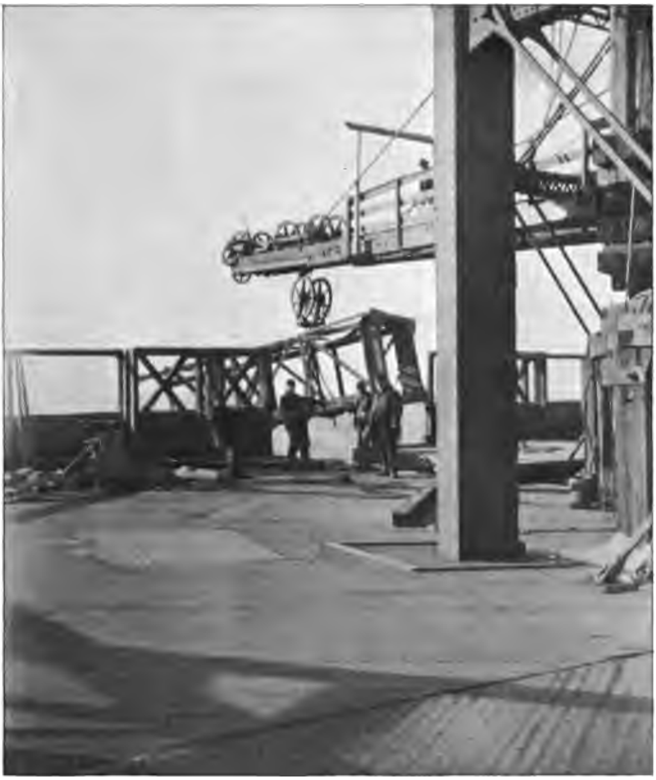
The west side of the platform was provided with an opening or hatchway for the passage of the material hoisted from the courtyard below, and when not in use was covered by a movable hatch, on rollers and track, of equal strength with the floor of the platform, which was designed to sustain about 250 pounds of material per square foot, this being sufficient for any member of the structure that might be stored upon it previous to erection.

The hoisting from the ground to the platform, through the hatchway, was by means of a steam trolley crane, originally used in the erection of the masonry of the tower, and which had been retained in position with a view to its further use on the dome. The track for the trolley was some 20 feet above the floor of the platform and fixed in position centrally with the hatchway. All material for the dome—except the lower members of the shell of the clock story, which could not be erected in place until the platform was removed—was raised by this crane.

The metal frame of the clock-story prism, including the cantilever floor-trusses, was erected by means of poles and boom-derricks, which at the start rested upon the main platform, and as the work progressed they were carried up, supported on and guyed to the framework.

For the erection of the pyramidal portion of the framework a timber scaffolding was erected centrally upon the cantilever floor; this was square in plan, and consisted of four vertical posts at the corners, braced by timber struts and ties. This scaffolding was about 10 feet square in plan, and extended in height to a point just below the level of the balcony floor.

To avoid the acute inclination of guy-lines that would result with an ordinary derrick at considerable elevation and with limited spread at base, the one used was composed of three arms, each of which was a distinct figure A derrick; they were hinged together at their feet, which were spread about 8 feet for stability sidewise; the three arms were capable of a fan-like rotation about their common hinge. For revolving the derrick, the base-block that formed the hinge was pivoted at the center and rested on iron wheels at the ends, rolling upon a circular track bolted to the floor of the scaffolding. The middle arm of the derrick acted as a mast, from the top of which blocks and falls lead to the outer ends of the two other arms, one of which was a boom to hoist the load while the other was in the

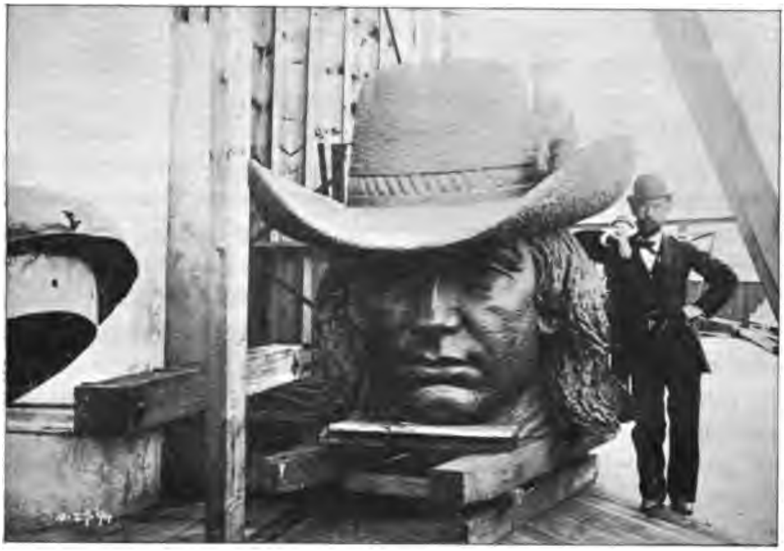


On Main Platform, 347 Feet above Street Level; Crane Hoisting Framed Pier.

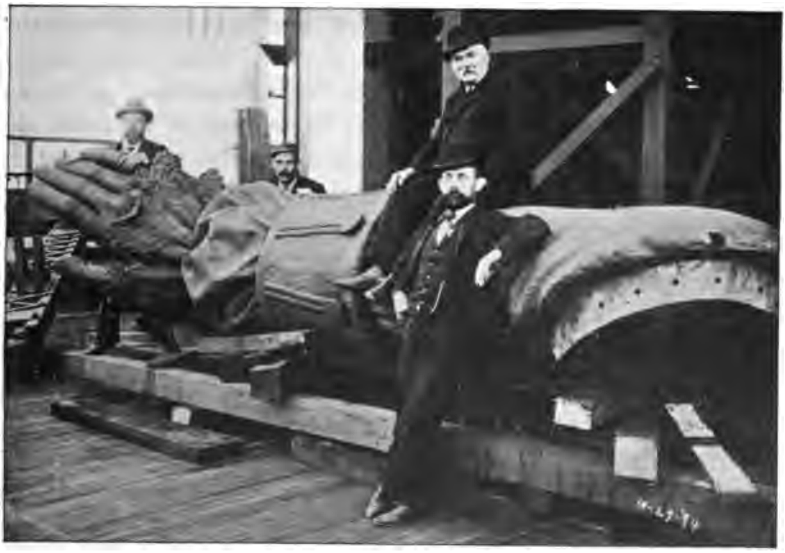
nature of a counter-boom, guyed to the structure below and holding the load to be hoisted in equilibrium. The inclination of the two side arms was maintained as nearly alike as possible. Two guy-lines with block and falls were used for holding the counter-boom, thus facilitating and providing safe means for revolving the derrick; the guys spread apart as they left the boom, and as one would be slackened and the other tightened the derrick would revolve until the tight line became perpendicular, thus taking all the strain; while the loose line would be fastened at some forward point, in the direction of the revolution of the derrick.

This method of erecting was used for all members of the framework to a point just below the balcony floor, after which the derrick was taken down and the arms utilized as separate derricks on different parts of the work; the scaffolding, however, was retained and its interior space utilized for supporting a temporary stair from the cantilever to the balcony floor, which still, in the absence of a permanent stair, remains.

That part of the pyramid above the balcony floor—that is, the three upper tiers of framing, apex-cap, Penn statue, and shell—was erected from a timber scaffolding, also square in plan, and surrounding this part of the work; it was composed of four vertical posts at corners about 14 feet apart, the feet of which rested upon and were anchored to the permanent brackets of the balcony gallery, which had been designed with this purpose in view; the parts were braced by horizontal timber-struts, forming nearly square bays, through which diagonal iron tie-rods intersected. Two posts on one side of the scaffolding extended from the balcony brackets to the height of the top of the apex-cap, about 42 feet, and the two opposite posts about 72 feet, or some 10 feet above the crown of Penn's hat. Heavy timber braces extended from the tops of the short to the upper ends of the long posts for the purpose of taking the strains from the guy-lines of a boom which was used for raising the parts to be erected from the main platform. This boom, which was stepped upon one of the struts of the scaffolding, specially braced for the purpose, swung between the two sides, and when horizontal just cleared the top of the short side of the scaffolding. The load on the boom was raised by means of rope and tackle leading over sheaves down to the hoisting engine on the main platform. The boom was of sufficient length so that when



HEAD OF PENN, ON MAIN PLATFORM.



RIGHT ARM OF PENN, ON MAIN PLATFORM.

in a nearly horizontal position the object raised would clear the greatest projections of the structure below.

The scaffolding was designed to resist a wind force of fifty pounds a square foot, and to withstand the lateral force from a maximum load of 10,000 pounds suspended from the end of the boom in any position. All connections were made by means of steel cover- or fish-plates, which were arranged to connect the posts and struts and take the steel pins of the diagonal tie-rods, the thickness of plates being so chosen as to obtain the proper bearing for pins and bolts.

The shell of the tower was erected from scaffolding carried by outlookers supported by and bolted to the framework of the tower; the arrangements were such as enabled the erection of sections of about 20 feet in height, when the scaffolding would be moved to a new position.

The shell of the clock story above the main platform was erected from a scaffolding extending from the platform the full height of the clock story.

When all the work had been erected from the level of the platform, the trolley crane was removed and a boom-derrick substituted. This swung from the top of the masonry on the west side of the tower, and was guyed to the framework through openings in the shell obtained by the removal of certain plates. With this boom the material in the scaffolding was lowered to the ground, and all remaining material raised or lowered. After the removal of the main platform the lower parts of the clock-story shell were placed in position from scaffolding resting upon the top of the marble cornice.

OBSERVATION OF MOVEMENTS OF THE TOWER WHILE IN PROCESS OF ERECTING THE DOME.

For the purpose of observing any possible movement of the tower due to the increment of weight from the dome, which might cause variations in the perpendicularity of the masonry substructure, the following arrangement was provided:

A plumb-line of thin piano wire was attached centrally with the plan and to the floor at the top of the masonry; it extended down 230 feet to the seventh floor of the tower or building, the lower end having a lead weight of 11½ pounds fastened thereto and immersed in molasses contained in a wooden box, about 15 inches square and 18 inches deep. This was firmly secured to the floor and placed centrally with the plan of the tower at this point. The two main axes of the plan were marked on the edges of the box as zero points, from which points, in both directions, divisions, $\frac{1}{32}$ of inch apart, were inscribed.

The position of the box was adjusted so as to bring the intersection of the zero points central with the plumb-line, which varied but slightly from the center of the plan of the tower at this point, indicating practically no divergence in the tower. A straight edge, laid upon the edge of the box, parallel with the zero points, and moved forward until it touched the wire, gave the amount of variation in two directions—north and south or east and west.

Observations of movement, direction and force of wind, as also the temperature, were recorded three times daily, except Sundays, and continued until the completion of the dome.

The zero point was set centrally with the plumb-line at noon February 20, 1892, the edges of the box being 109 and the suspension point of the wire 339 feet above the street-curb level.

It will be seen from the table below that in no case was the deviation permanent, and the only practical value of the observations is that they disclose the fact that the additional weight of 1000 tons upon the tower did not alter its perpendicularity, and that variation in temperature in connection with the changes in the position of the sun for the respective seasons does cause movements.

Wind storms of considerable force had no effect whatever, opportunity to make observations having been given by several storms of sufficient force to sway factory chimneys.

On September 1, 1895, at 6.15 A. M., a slight shock of earthquake, of sufficient force to awaken persons from a sound sleep, was felt in Philadelphia and vicinity. The shock was not noticed by either of the two watchmen stationed at the top of the masonry work of the tower. A strong gale from the northwest was blowing at the time.

TABLE OF DEVIATION OF PLUMB-LINE.

The following tables give the average maximum deviation of the plumb-line, the average temperature, and the difference in deviation, monthly, for the years from 1892 to 1896, inclusive, in decimals of an inch:

	Temp.	*Average maximum deviation.*				*Difference in deviation.*			
	F.	N.	S.	E.	W.	N.	S.	E.	W.
January, . . .	35.5	.078	.109	.058	.067	.0	.031	.0	.009
February, . .	35.0	.083	.088	.057	.07	.0	.005	.0	.013
March, . . .	44.0	.097	.093	.07	.07	.004	.0	.0	.0
April, ...	56.4	.178	.078	.112	.072	.1	.0	.04	.0
May, ...	66.8	.175	.0	.081	.062	.175	.0	.019	.0
June, ...	75.6	.197	.0	.084	.062	.197	.0	.022	.0
July, ...	79.0	.225	.0	.07	.072	.225	.0	.0	.002
August, . . .	79.0	.231	.125	.106	.078	.231	.0	.026	.0
September, . .	73.5	.218	.0	.114	.07	.218	.0	.044	.0
October, . . .	60.0	.141	.0	.062	.078	.141	.0	.0	.016
November, . .	50.0	.105	.046	.083	.093	.059	.0	.0	.01
December, . .	40.6	.088	.109	.078	.109	.0	.021	.0	.031

It will be noticed that in the months of January, February, and December the deviations north and south nearly canceled each other. From March the deviation continued north, increasing gradually and reaching a maximum in August, when it gradually decreased to November.

The deviation east and west is peculiar, being west in January, February, October, November, December, and the hottest month—July. The remaining months show an easterly deviation.

The movement of the tower is due to variation of temperature resulting from the relative position of the sun as affecting the four sides of the tower, they being normal to the cardinal points of the compass.

SPECIFICATIONS OF MATERIAL IN FRAMING.

The rules and methods in vogue by the principal bridge companies in standard specifications were adopted for the physical qualities of the respective materials and the proportion of members. The essentials were:

IRON.

Ultimate strength, tensile, ...	50,000 lbs. per sq. in.
Elastic limit, ...	26,000 " "
Elongation, minimum, ...	18 per cent. in 8 inches.

ANGLES AND OTHER SHAPES.

Ultimate strength, tensile, ...	48,000 lbs. per sq. in.
Elongation, minimum, ...	15 per cent. in 8 inches.

PLATES.

Ultimate strength, tensile,	46,000 lbs. per sq. in.
Elongation, minimum,	10 per cent. in 8 inches.

STEEL.

Ultimate strength, tensile,	54,000 to 62,000 lbs. per sq. in.
Elastic limit,	25,000 to 30,000 " "
Elongation, minimum,	26 per cent. in 8 inches.

Bending tests and other requirements were enforced.

PROPORTION OF PARTS.

All parts are so proportioned that the working stresses in pounds per square inch will not exceed, for—

	Pounds.
Tie-bars,	15,000
Plates and shapes,	12,000
Bending, extreme fiber strains, pins, steel,	20,000
Shearing, rivets,	7,500
Shearing,	10,000
Bearing, steel,	15,000
Bearing, iron,	12,000

Compression.—When the length of the member does not exceed fifty times its least radius of gyration, 10,000 pounds. When this ratio exceeds 50 to 1, Rankine's formulæ for struts have been used, thus:

Square ends:

$$S = \frac{10{,}000}{1 + \frac{l^2}{36{,}000\,r^2}}$$

Pin and square ends:

$$S = \frac{10{,}000}{1 + \frac{l^2}{24{,}000\,r^2}}$$

Pin ends:

$$S = \frac{10{,}000}{1 + \frac{l^2}{18{,}000\,r^2}}$$

In which: S = Working stress per square inch, in pounds.
l = Length of member in inches.
r = Least radius of gyration of cross-section.

Alternate strains of compression and tension were provided for by modifications of stresses in accordance with Wohler's law, in which—

Let $S_1 =$ modified stress, and $S =$ initial stress as given above; therefore, for the stresses of opposite kinds—

$$S_1 = S\left(1 - \tfrac{1}{2}\,\frac{\text{min. stress}}{\text{max. stress}}\right).$$

All tie-bars were submitted to an actual pull of 20,000 pounds per square inch in a testing machine before delivery.

External Forces.

The forces affecting the structure are:

Dead loads due to the weight of—

1. Framework, primary, other than that supported directly on masonry.
2. Three floors.
3. Statue of William Penn.
4. Framework, secondary, partly that supporting clock-story cornice and all of pyramid.
5. Shell of pyramid and part of clock-story cornice.

Live loads, due to crowds on the three floors, estimated at 100 pounds per square foot of floor area.

Wind.—The wind assumed as acting horizontally and with a pressure of 50 pounds per square foot on a flat surface perpendicular to its direction.

The resultant average pressure per square foot on a plane equal to the outline of the body, or its diametrical plane, is:

1. The clock, square in plan, 50 pounds.
2. The pyramid, octagonal in plan, 40 pounds.
3. The part between the balcony gallery and the base of the Penn statue, cylindrical in plan, 32 pounds.
4. The Penn statue, oval in plan, 35 pounds.

Note.—The vertical forces in the chords, from the live load on floors, are considered as not acting simultaneously with those from the maximum wind forces, the possibility of crowds assembling on the floors during a wind storm exerting a pressure of 50 pounds per square foot being assumed as an improbable condition.

Wherever eccentric or compound strains occur,—such as, for instance, the bending moments in the chords, from the load on the brackets that project from them,—in addition to the axial strains, the cross-section of the member affected is modified accordingly.

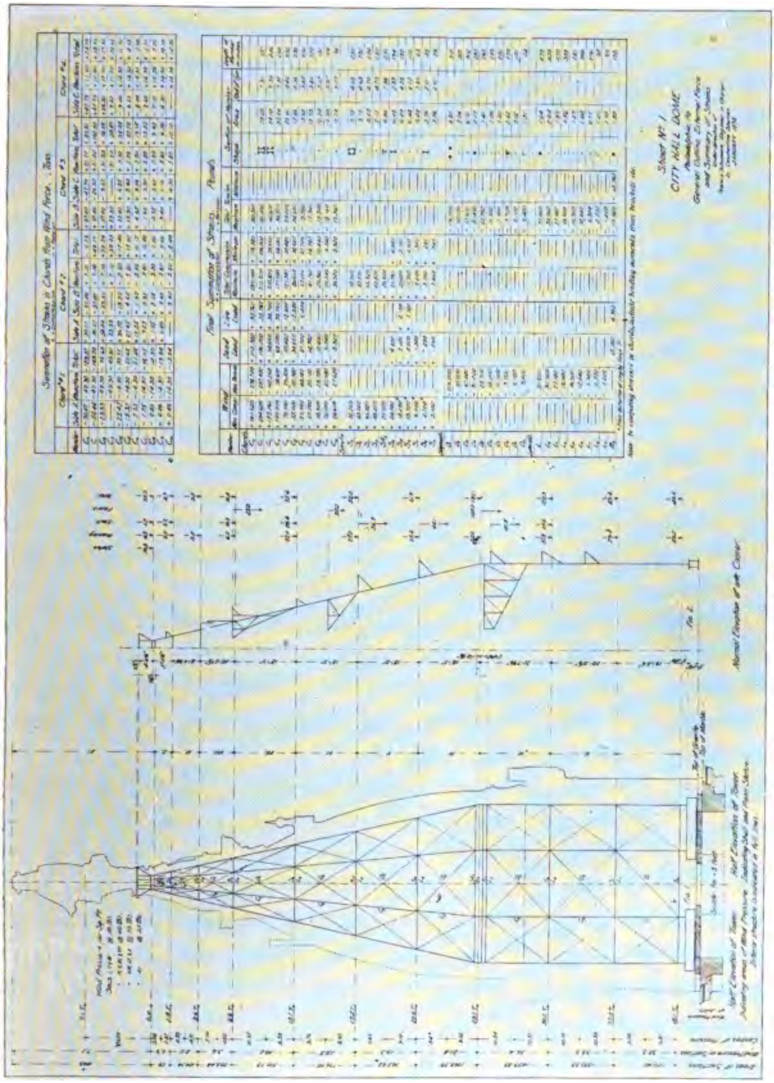


Diagram of Strains, Sheet No. 1.

Where the bending moment becomes a greater factor,—such as from the cantilever trusses, or at the junction of the prism and pyramid,—the resultants are counteracted by special members, struts, or ties respectively.

DETERMINATION OF STRAINS.

When the general scheme of the framing had been decided upon,—this being quite similar to that of the writer's first design, made for Mr. McArthur,—exhaustive search was made for literature that would relate thereto. Except approximate methods of J. W. Schwedler, applied in computing the strains in the spire of St. Peter's Church at Hamburg, Germany,—a structure built of iron in the early seventies,—nothing directly applicable was discovered.

The formulæ of Schwedler, while approximate, were considered on the safe side, because an important structure executed according to them had stood the test of over ten years' trial, and, therefore, in lieu of anything better at the time, they were adopted for computing the strains in the tower.

Since then, however, about 1893, the writer has succeeded in evolving exact methods, which, in connection with the actual weights of construction at hand, have been applied in the following computations, and which serve as a check upon the previous work.

Having decided upon the external forces, the resultant strains in the structure were found in the following manner and order:

The statue of Penn and apex-cap, down to the top of pyramidal chords, were, by reason of their compact and, in a sense, rigid construction, considered a homogeneous body.

The bending moments and reactions from the wind, acting at the center of gravity of the vertical plane bounded by the outline of the respective parts, were determined for horizontal sectional planes as follows: One through the smallest part of the legs of the statue; one at the top of the base-plate, cutting the bolts that hold down the statue and tree stump; one at the bottom of base-plate, cutting the eight square eye-bolts to the apex-cap; and one through the juncture of the apex-cap and top of chords.

For the planes through legs and top of base-plate, the section being unsymmetrical, the least moment of inertia was computed, as also the moments of resistance and maximum fiber stresses.

At the plane through the juncture of apex-cap and chords the resultant forces from the parts above are held in equilibrium by the framework of the tower. The dead load, which is central with the

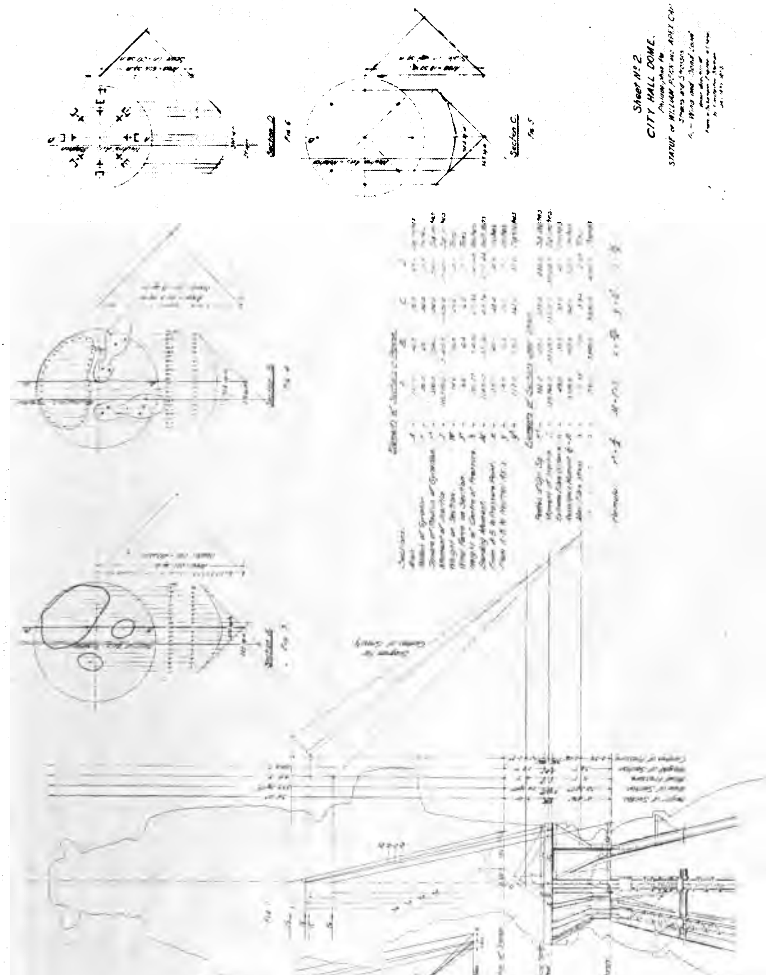


DIAGRAM OF STRAINS, SHEET NO. 2.

center of gravity of the plane, is carried equally by the eight chords, while the vertical components from the bending moment of the wind vary as their distance from the axis of rotation, which also passes through the center of gravity of the plane, in this case a symmetrical section. The horizontal components, or shearing force, however, is distributed in the six effective sides of the octagon, being the two parallel and the four inclined sides with the direction of the wind, in accordance with the theory of strains in the framework, as expounded below.

THEORY OF STRAINS. DEFINITION OF PARTS AND THEIR PURPOSES.

The primary structure, which consists of a prism surmounted by a pyramid, both regular octagons in plan, is formed of longitudinal or meridional members—chords—placed at the apices of the octagon to resist the bending moment from the transverse force of the wind, and to support the vertical forces from weight of construction and superimposed loads.

Horizontal ring-struts connect the chords and form the sides of octagonal frames, a series of these frames subdividing the structure into zones or sections; these struts are to resist the transverse or shearing force, and eventually the deformation of the octagonal frames, as also the components from the vertical forces in the pyramid.

The deformation of the eight panels that form the sides of the zones, caused by the shearing force, is resisted by diagonal members, ties, or struts, depending upon the character of the strain.

Deformation in Plan.—The shearing force from the wind, acting at the, to an extent, flexible joints of the apices of the polygonal frame, is held in equilibrium by the resultants from the diagonals and chords, provided the polygon retains its form. The wind, however, acting upon one side of the tower only, tends to deformation by compressing the polygon in direction with, and expanding perpendicular to, the wind, the apices on the windward side being forced inward. Hence the adoption of lateral ties in the plane of the polygon to maintain their form and in accordance with the following reasoning.

A regular polygonal frame, formed of bars hinged without friction at the apices, will be in equilibrium when radial forces, of equal intensity, at each end of the apices act toward the center of the polygon. When one or more of these forces are removed, deformation will occur; each apex from which the force is removed will have an outward movement, in amount equal to the force removed, and will be a resultant of the remaining forces, which cause the two adjacent apices to approach each other. This force of approach is a component of

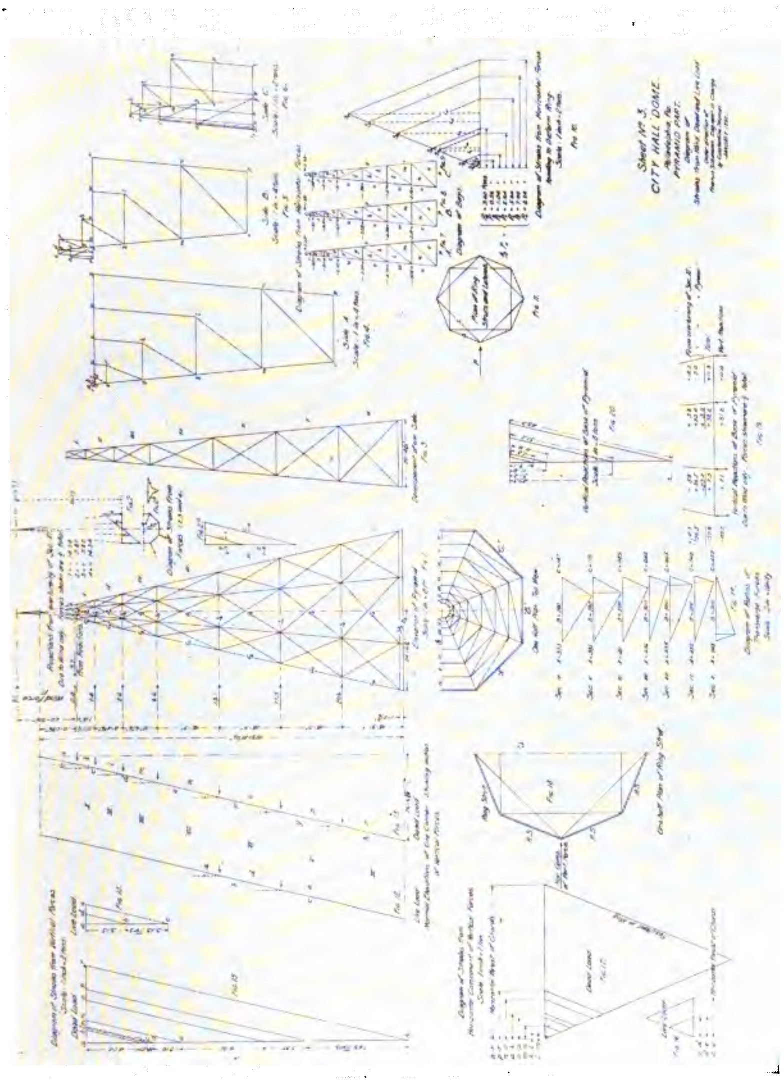


DIAGRAM OF STRAINS, SHEET NO. 3.

the outward—*i. e.*, the inward—force, and is, therefore, determined and to be counteracted by a strut member. Inverting the process, if only one force act inwardly at an apex, the two adjacent apices will move apart. It is to prevent this that tension members are applied. As all apices are liable to this condition, lateral rods, ring ties, are provided accordingly, thus forming a continuous system of interlacing of laterals.

As the strains in the laterals are resultants of a part of the compressive strains in the ring-struts, due to the shearing force, their insertion will not increase the strains in any other member.

The octagonal frames, sensibly rigid, transmit the shearing force equally to all the eight joints at the apices of the octagon, where it is resisted by the respective diagonals and chords in proportion to their efficiency, which is dependent upon their respective coincidence with the direction of the external forces affecting them.

GENERAL PRINCIPLES OF STATICS APPLIED.

1. All forces acting at a joint shall balance each other.

2. The resultant opposing the displacement of members meeting at a joint is central at the middle of the joint.

3. A compound or primary structure may be subdivided into a combination of simple or secondary trusses or frames to resist the external forces. In such combinations the same members often form parts of different frames.

4. When the same member forms at the same time part of two or more different frames, the strain on it is the resultant of the several strains to which it is subject by reason of its position in the several frames.

5. In compound structures, several frames, without being distinguishable into primary and secondary, are combined in such a manner that certain members are common to two or more of them; their strains are to be determined as in No. 4.

6. When the frames act all in one direction, the magnitude of their resultant is their sum, and their resultant will pass through their common center of gravity.

7. When the forces act in contrary directions: Find, separately, the magnitude and resultant of the forces which act in two contrary directions, respectively; if the two resultants are unequal, find the final

resultant; if they are equal, they form a couple, and have no single force as a resultant.

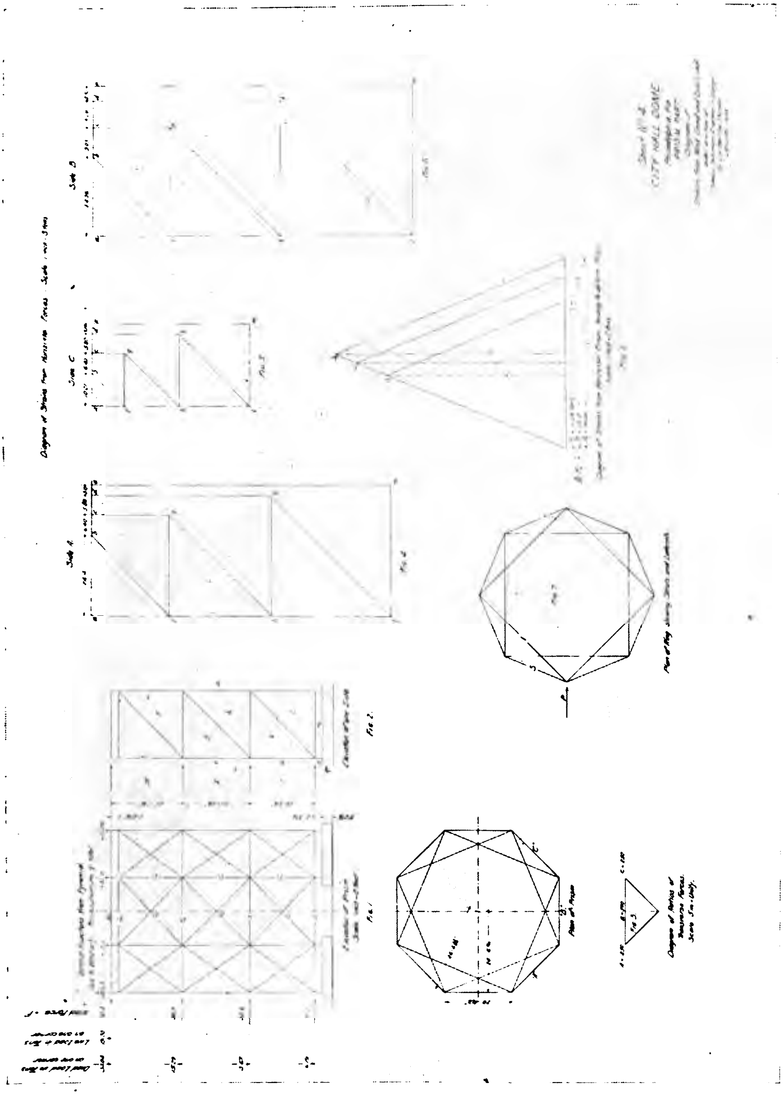


DIAGRAM OF STRAINS, SHEET NO. 4.

8. When the center of pressure is at the center of magnitude of the pressed surface, the intensity will be uniform throughout the surface.

9. When the center of pressure varies simply as the perpendicular distance from a given axis, the pressure will be uniformly varying.

10. In compound framed structures, composed of secondary frames combined into a primary, each secondary frame will have its own axis of rotation; their common axis, that of the primary frame, may or may not be at the center of gravity of the plane of rotation, as in a homogeneous body.

11. If a frame be acted upon by any system of external forces, and if that frame be conceived to be completely divided into two parts by an ideal surface, the stresses along the members which are intersected by that surface balance the external forces which act on each side of the two parts of the frame.

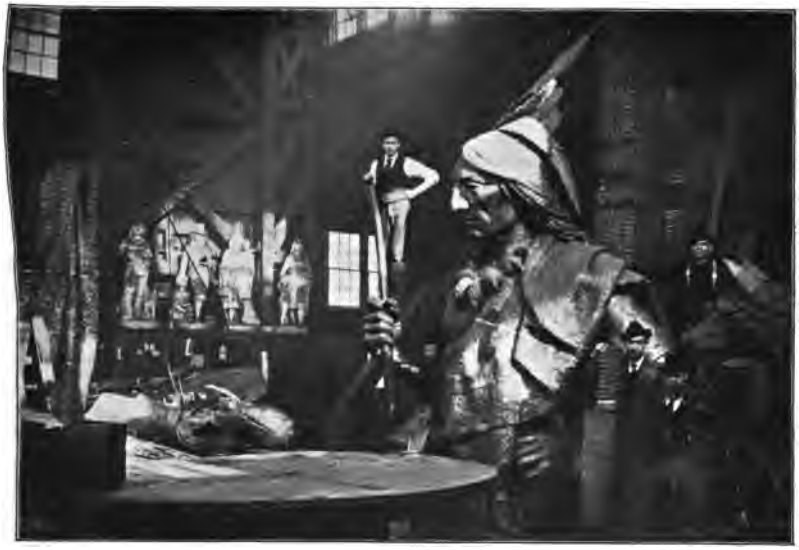
12. If not more than three members are cut by the ideal surface, the problem is determinate; if more than three members are cut, the problem is or may be indeterminate.

EFFICIENCY OF THE WEB TO TRANSMIT STRESSES.

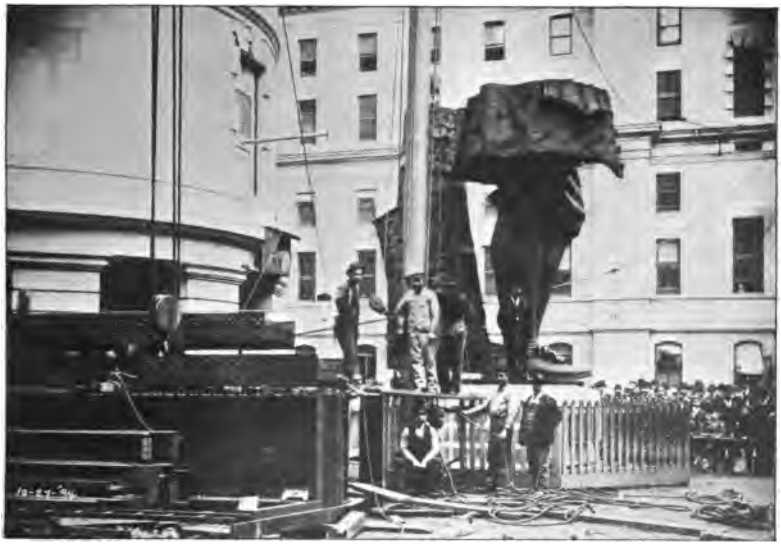
The theory generally accepted for the flexure of beams of solid section is deficient, in that it ignores the efficiency of the web portions for transmitting the stresses from fiber to fiber, and ultimately to the flanges or outer fibers. By reason of a want of homogeneity and a consequent diminished efficiency, other than uniformly varying stresses may occur in the section; the axis of rotation, or neutral axis, may not pass through the center of gravity of the section, but alongside of it.

In framed beams, especially such as contain intermediate chords, the members between the chords, constituting the web, assume an importance paramount with the chords for resisting the bending moment; the shearing force first asserts itself, to be resisted by the web, which in turn transmits to the chords, to be finally held in equilibrium by the reactions at the points of support.

When the web bracing of the subdivisions of a framed beam, which are formed by a series of chords, are of equal efficiency, the inner chords—that is, those nearest the neutral axis—cease to act as members to resist bending directly, but become web members to transmit transverse forces to the outer chords, which finally resist the total bending moment caused by the transverse forces. Were the beam a cantilever,



HEAD OF INDIAN CHIEF AT FOUNDRY.



ERECTING PENN STATUE IN COURTYARD, CITY HALL.

for example, the reaction at the points of support would be null for the inner chords, while the outer ones would have reactions equal to the bending moment. The inner chords may come into action to resist bending, if the web divisions vary in efficiency to transmit the transverse forces.

The maximum efficiency of a web is when the plane, in which the members lie, coincides with the direction of the external force; the efficiency decreases with the inclination between them. A case in point would be a cantilever, rectangular in section, and composed of four chords, one at each corner, braced with ties and struts, subject to an external transverse force which would cause the axis of rotation to be at an angle of, say 30°, with one of the sides; the two sides least inclined to the force would be more effective than the others. The proportion of the total bending moment transmitted to the points of support by a web and its chords will be as its efficiency. Thus, the plane embracing the diagonals of a side perpendicular to the external transverse force would be inefficient and incapable of transmitting any bending moment.

APPLICATIONS TO PRISMS AND PYRAMIDS.

When the structure is subject to vertical forces only, the strains in diagonal and ring-struts of a prism will be zero, and the vertical forces will be resisted equally by the chords, acting as columns, while in pyramids the ring-struts and chords will resist the horizontal component of the vertical forces and vertical forces respectively.

In prisms the axis of rotation of the moments from the transverse forces will pass through the center of gravity of the horizontal plane, while in pyramids with web bracing it moves toward the side from which the forces act, being due to the diminished efficiency of the web of the opposite sides of the polygon, the transverse forces being assumed to be normal to one of the sides of the polygon with an even number of sides.

In a pyramid the efficiency of the diagonals in the sides inclined to the direction of the force tends to diminish toward the apex; hence the center of action of the external transverse forces, or lever-arm of the bending moment of the respective side, is shorter than in a side having more efficient diagonals.

Each side of the polygon, treated separately, will have its own axis of rotation, and the common axis of rotation for the combined sides will be at their common center of gravity.

Pyramids without web bracing, to which belongs the apex portion of any pyramid, are treated similarly to prisms; each side is considered as a secondary truss or frame. When a side of a pyramid is developed to normal plane, upon which the lever arms are measured for the bending moments, the strains found will give reactions in the same plane of development; the vertical reaction for the primary or combined structure will be the reaction in the plane multiplied by the cosine of the inclination, when in final position with a vertical.

One of the Four Bronze Eagles. 14 Feet 6 Inches from Wing to Wing; Height, 9 Feet; Weight, 6620 Pounds Each.

The reactions from the bending moment in an apex of a pyramid, or one without web bracing, the chords forming a joint, are directly as their distances from the axis of rotation, which will pass through the center of gravity of the polygonal plane of rotation.

When a pyramid surmounts a prism, the strains in each should be obtained separately, the vertical reactions from the moments in the pyramid being first determined and applied to the prism as external forces. Without separate treatment, the determination of resultants and strains at the joints of intersection of the prism and pyramid become complicated and confusing.

As heretofore stated, the horizontal plane between the zones must be capable of resisting deformation; they transmit the total shearing force, acting at the plane, to the joints at the corners of the polygon.

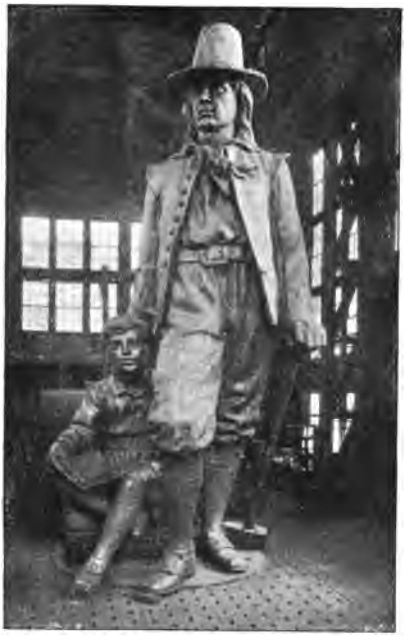
The efficiency of a diagonal in the sides of a pyramid inclined to the direction of the transverse force varies as the cosine of its inclination, on a horizontal projection, with the direction of the transverse force. Where the inclination is 90° the diagonal ceases to act, and where the inclination is 0°, or parallel to the force, it is of maximum efficiency.

METHOD OF PROCEDURE FOR OBTAINING STRAINS, SPECIALLY APPLICABLE TO OCTAGONAL STRUCTURES; JOINTS HINGED.

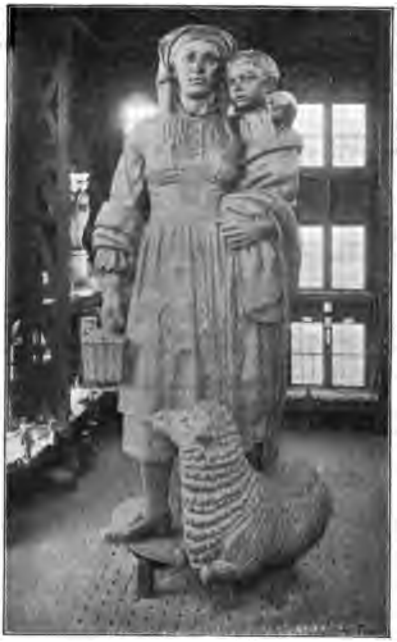
1. Proportion the transverse forces, from the wind, acting as a shearing force at each joint of the horizontal plane, in accordance with the efficiency of the diagonals affected.
2. Develop separately each side of the structure, constituting secondary trusses or frames, in which the strains differ, to a normal plane, being the two oblique sides on the windward and leeward sides of the structure and the sides parallel to the direction of the wind; the sides perpendicular to the wind being in effect null.
3. Proceed to determine the strains by any desired method,—analytic, graphic, or otherwise,—using for external forces the allotment found for each separate side of the octagon developed; the development of a side being now a plane in line with the direction of the force.
4. When the strains have been obtained for each separate division of the octagon, conceive the sides to be united on a line central with the chords, in which the strains will now be the resultant of the strains found when separated.
5. The strains obtained for the secondary frames, whose planes are inclined to the direction of the transverse force, must provide for the decrease in efficiency of the members when in their final position in the structure.

RÉSUMÉ.

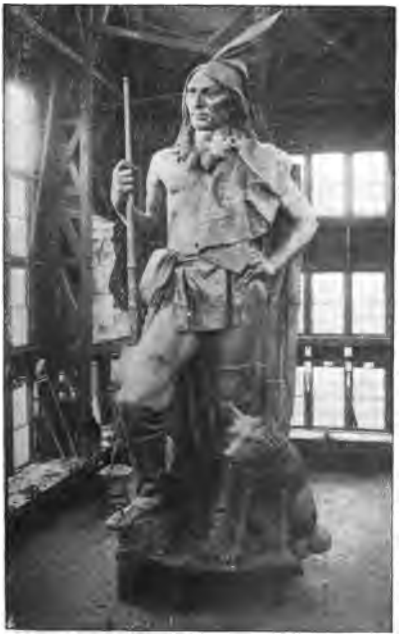
1. The horizontal planes must be sensibly rigid to resist deformation. The total shearing force existing at a plane is transmitted by it to the joints at the corners of the polygon.
2. The deformation of the sides of the zones is resisted by their respective diagonals in a ratio depending upon the inclination of their



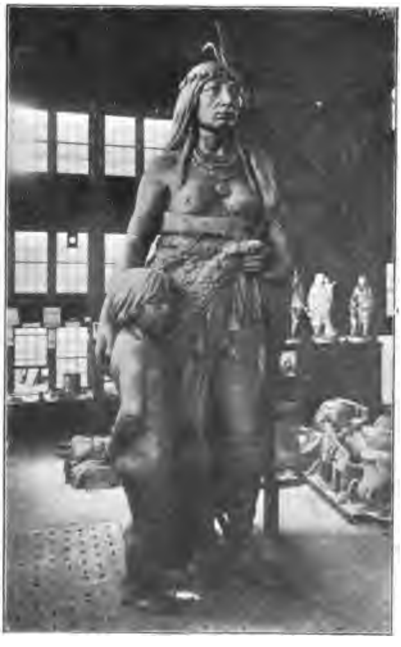
Early Settlers: Swedish Man and Boy. Bronze Statue, 24 Feet High; Weight, 17,300 Pounds.



Early Settlers: Swedish Woman, Child, and Lamb. Bronze Statue, 24 Feet High; Weight, 19,480 Pounds.



Indian Chief and Dog. Bronze Statue, 24 Feet High; Weight, 23,760 Pounds.



Indian Woman and Boy. Bronze Statue, 24 Feet High; Weight, 19,540 Pounds.

vertical planes (of inclined sides with force) with the direction of the external force.

3. The reactions resulting from the transverse force at the apex portion of a pyramid will vary as their distances from the axis of rotation, which coincides with the center of gravity of the horizontal plane from which the apex springs.

4. The vertical forces, when their center of action coincides with the vertical axis of the structure, will be equally divided between the eight chords.

FORMULAS FOR THE DETERMINATION OF STRAINS IN OCTAGONAL PRISMS.

REFERENCE.

F = Total transverse force, from wind, acting on a horizontal plane.
r = Ratio of F acting on a side of the plane, parallel with force.
s = Shearing force acting upon a ring-strut.
P = Force tending to deform a horizontal plane, normal to an apex of the plane.
S = Strain in ring-strut from P.
T = Tension in ring-ties from P.
C = Strain in chords, primary frame.
c = Strain in chords of secondary frames, developed.
t = Tension in diagonals.
p = Vertical forces from dead load and superimposed load.
b = Distance between centers of chords.
f = Proportion of F acting on a side, A, B, and C respectively, parallel to side.
M = Bending moment; R = reaction at supports; h = vertical height.

SIDES A AND C.

$$r_1 = r_3 = \frac{\cos^2 Z^\circ}{1 + 2\cos^2 Z^\circ} = \frac{0.5}{1 + 0.5 + 0.5} = 0.25;$$

SIDE B.

$$r_2 = \frac{1}{1 + 2\cos^2 Z^\circ} = \frac{1}{1 + 0.5 + 0.5} = 0.50$$

$$f_a = f_c = \frac{Fn}{2\cos Z^\circ} r_1; \ f_b = \frac{Fn}{2} r_2.$$

FORMULAS FOR THE DETERMINATION OF STRAINS IN OCTAGONAL PYRAMIDS.

REFERENCE.

F = Total transverse force, from wind, acting on horizontal plane.

f = Proportion of F acting on a side, A, B, and C respectively, parallel to side.

r = Ratio of F acting on a side parallel with force.

m = Bending moment at joint in question, secondary frame.

c = Strain in chords, secondary frame.

C = Strain in chords, primary frame, resultants of c,

S = Shearing force at joint in question.

s = Strain in ring-strut, to which add component from vertical load.

t = Strain in diagonal.

K = Horizontal component from C, windward chord.

k = Horizontal component from c, leeward chord.

R = Reaction in plane of development.

V = Vertical component of R when side or secondary frame is inclined to final position in structure.

h = Height from joint in question to f_n; measured from m_n.

x = Perpendicular from opposite apex to chord; lever arm.

a° = Angle of plane, embracing diagonal, with direction of force W.

u° = Inclination of a side with a vertical.

y° = Angle between a horizontal and diagonal, or strut when inclined.

Y° = Inclination of a chord with a vertical, on a radial plane.

z° = Inclination of a chord to a vertical; side developed.

SIDE A. SIDE B.

$$r_1 = \frac{\cos^2 a_1}{\cos^2 a_1 + \cos^2 a_2 + 1}; \quad r_2 = \frac{1}{\cos^2 a_1 + \cos^2 a_2 + 1};$$

SIDE C.

$$r_3 = \frac{\cos^2 a_2}{\cos^2 a_1 + \cos^2 a_2 + 1}.$$

FOR AN APEX PART.

$$r_1 = \frac{\cos^2 45^\circ}{1 + 2\cos^2 45^\circ} = 0.25; \quad r_2 = \frac{1}{1 + 2\cos^2 45^\circ} = 0.50;$$

$$r_3 = \frac{\cos^2 45^\circ}{1 + \cos^2 45^\circ} = 0.25$$

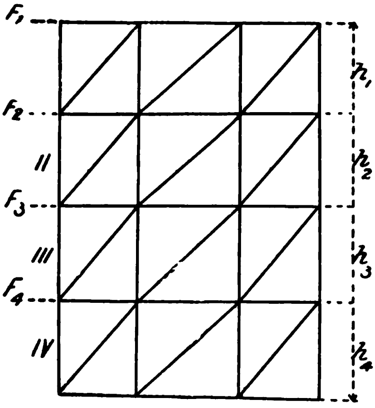
$$f_1 = \frac{F}{2\cos 45^\circ} r_1; \quad f_2 = \frac{F}{2} r_2; \quad f_3 = \frac{F}{2\cos 45^\circ} r_3.$$

STRAINS IN SECONDARY FRAMES FROM TRANSVERSE FORCE.

PRISMS.

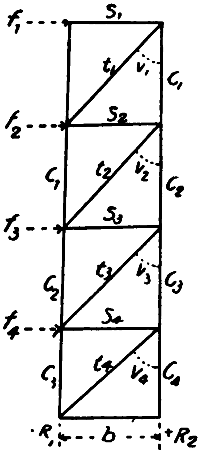
$$s_n = f_n + s_{n-1}; \quad t_n = s_n \operatorname{cosec} V^\circ_n; \quad c_n = \frac{S_n h_n}{b} + c_{n-1}; \quad R = R_1 = \frac{M}{D}.$$

PRIMARY FRAMES.

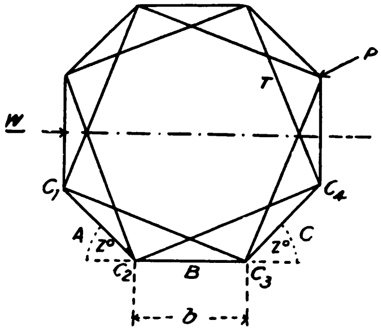


ELEVATION OF PRISM.

SECONDARY FRAMES.



ELEVATION OF SIDES, A, B, OR C.



PLAN OF PRISM.

STRAINS IN PRIMARY FRAMES.

$$T = \frac{P}{2} \text{ cot. } \frac{Z^\circ}{2} = \frac{P}{2}\, 2.4142; \quad S = \frac{P}{2} \text{ csc. } \frac{Z^\circ}{2} = \frac{P}{2}\, 2.613;$$

c_2 and c_3 = resultants of c of secondary frames combined.

STRAINS IN SECONDARY FRAMES FROM TRANSVERSE FORCE.

PYRAMIDS.

$$c_n = \frac{m_n}{X_n}; \quad m_n = f_{n-1}\, h_{n-1} + f_{n-2}\, h_{n-2} + \ldots\ldots;$$

$$K = c_n \sin. Z^\circ{}_n; \quad k = c_n \sin Z^\circ{}_n;$$

$$\ldots + f_{n-2} + \ldots\ldots; \quad s_n = (s_n - K_n - k_n);$$

$$\ldots - K_n - k_{n+1}) \sec. Y^\circ{}_n;$$

$$\ldots = R_1 = \frac{M}{b}; \quad V = R \cos u^\circ;$$

… resultants of c combined.

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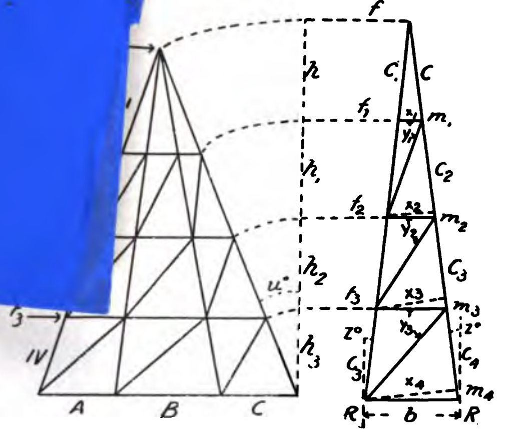
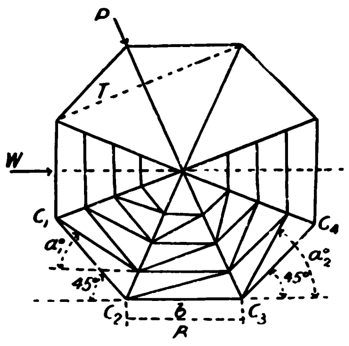
…RIMARY FRAME. SECONDARY FRAME.



DEVELOPMENT OF SIDES
A, B, OR C.



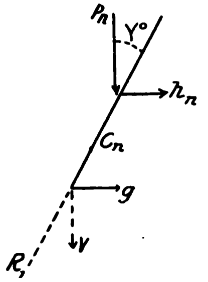
A B C

PLAN.

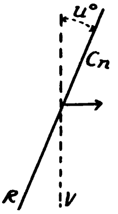
STRAINS IN PRIMARY FRAME.

REFERENCE.

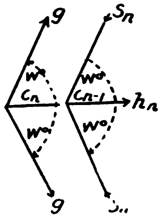
p = superimposed load, dead and live, acting vertically at joint.
h = horizontal component acting toward center of tower.
c = component in direction of chord.
s = component in direction of ring-strut.
g = strain in lower ring-strut, tension.



RADIAL PLANE.



NORMAL TO SIDE.



PLAN.

$$c_n = P_n \sec Y° + c_{n-1};\ \ h_n = P_n \tan Y°;$$

$$s_n = \frac{h_n}{2} \sec W°; \quad g = \frac{c_n \sin Y°}{2} \sec W°; \quad V = c_n \cos Y°;$$

$$T = \frac{P}{2} \cot \frac{Z°}{2} = \frac{P}{2}\, 2.4142; \ \ s = \frac{P}{2} \csc \frac{Z°}{2} = \frac{P}{2}\, 2.613.$$

EXPLANATION OF STRAIN DIAGRAMS.

SHEETS 1, 2, 3, AND 4.

The strains in the framework were obtained by means of graphic statics, that method being found more simple and expeditious than the analytic, which has been used only in such cases where its choice seemed desirable and more directly applicable. Generally, only one-half of the dome is considered, the two halves being alike, each being subject to half the total external forces.

SHEET No. 1 (PAGE 55).

Figure 1 shows elevation of primary frame of dome divided into eleven sections or zones, with outline of shell and Penn statue. On the left are given the area of sections exposed to the wind in square feet, the pressure in tons, the height to center of pressure, and the total pressure at each juncture of zones. The designation of members by letters is inscribed, and corresponds with those in the table of summation of strains.

Figure 2 is a diagram of members that lie in a radial plane through the center of a chord; it shows the center line of chords, floor trusses, supporting brackets, and apex-cap. To the right are given the weight of statue, framing, shell, and floors, with their points of application.

The table of strains explains itself.

SHEET NO. 2 (PAGE 57).

Figure 1 shows Section XI, being the outline of the Penn statue, apex-cap, and elevation of upper portion of framing.

Figure 2 is a diagram for determining resultants from wind and dead load, as also the center of action for wind.

Figures 3 to 6, inclusive, are sectional planes at various points, showing neutral axis for least moment of inertia and axis of rotation.

The table of elements fully explains itself and its relation to the other figures.

SHEET NO. 3 (PAGE 59).

The various figures explain themselves, special remark being necessary only as follows:

The statue and apex-cap, considered as a homogeneous body, tends to overturn about its axis of rotation in the plane of support at the top of chords or framing, from the transverse force of the wind, acting at the line of its application with a lever arm of 20.79 feet. See figure 2.

The vertical reactions from the transverse force at the points of support lie in vertical planes parallel with the force, and vary as the distance from the neutral axis.

From the vertical reactions, the respective horizontal forces and components in direction of the inclined chords, all in a plane radially through the respective chords, are determined as shown in figure 2 *a*.

The horizontal radial force resisted by the inclined chords gives resultants opposite in direction to the direct shearing force of the wind in amount equal to the sum of the components parallel with the direction of the transverse force. See diagram, figure 2 *b*.

This opposite force, less the direct shearing force, is proportioned into the secondary frames, or sides A, B, and C, in accordance with the efficiency of the respective web members, as heretofore explained.

The strains in chords from the overturning action of Section XI, as also those from the dead and live loads, are treated separately, and given in table, Sheet No. 1; those from overturning, in column headed "Reactions."

SHEET No. 4 (PAGE 61).

The figures fully explain themselves, the results being contained in table of summations, Sheet No. 1.

In conclusion, I would remark that problems of the kind under consideration at first appear difficult and confusing, but are in reality simple and determinate when once dissected and brought within the laws of statics.

The effect of variations in temperature do not complicate the investigations, because the structure is free to vary its dimensions without altering its proportions. The only point in which caution is necessary is when the structure rests upon the masonry; the metal in the framing having a different rate of expansion or contraction from that of the masonry, the details must be such as to permit movement. This is provided for by means of the four heavy girders which carry the eight chords, the anchor bolts to masonry being free to move and girders to slide.

Care was taken to so adjust the turnbuckles or swivels that proper and proportionate initial tension occurred in the diagonal tie-rods.

Provision is made for dissipating charges of electricity due to atmospheric disturbances, to which elevated metallic structures are more or less liable. Heavy iron wire cables, placed within flue spaces built in the masonry, connect the metal work of the dome with certain water pipes laid under ground adjacent to the tower, thus acting as conductors for the passage of any electric charges away from the dome. The efficiency of the device was made apparent during the erection of the structure, when several severe electrical storms were experienced.

All water from rainfall or snow is gathered by a cast-iron electroplated gutter placed at the base of the dome, and on top of the marble cornice. The gutter extends around the dome, is about 3 feet wide and 18 inches deep, lined inside with 64-ounce sheet copper with expansion joints, and laid upon a Portland cement base, graded from each corner of the tower down to the middle of a side, where funnel-shaped copper outlets lead to 6-inch diameter iron pipes that connect with the sewers of the building. The inside edge of the gutter, which extends up back of the lower sheets forming the shell of the dome, is three inches higher than the outside edge, so that in the event of a possible overflow from a stoppage of the down pipes the flow would be outward, and away from the tower.

DISCUSSION.

THE PRESIDENT.—What is the weight of the masonry replaced by the iron construction?

MR. SCHUMANN.—If the dome had been built of masonry, and the thickness of the present walls, as originally designed, the total weight would have been about 60,000 tons greater. As it is, the pressure on the soil is considerable, being about 9½ tons to the square foot.

THE PRESIDENT.—What is the nature of the sub-foundation?

MR. SCHUMANN.—The underlying soil is a reddish clay, mixed with sharp pebbles, very stiff and hard to pick and difficult to soften with water. Many of you will recognize this description as of a soil possessing excellent qualities for foundations. The tension at the bottom chords on the windward side, under a wind force of fifty pounds to the square foot, is about eighty tons. Bronze bolts in addition to steel bolts are used for securing the Penn statue to the bronze base-plate as a guard against galvanic action, which might affect the steel bolts, although all means have been used to prevent the accumulation of moisture around them. The bronze bolts alone are sufficient to secure the statue should the steel bolts be weakened from corrosion. Portland cement was thoroughly packed within the feet of the statue and around the heads of the bolts as a protection against moisture.

THE PRESIDENT.—What has been the entire settlement of the tower?

MR. SCHUMANN.—The upper portion of the tower, about eighty feet above the ground level, has settled a little over four inches, but the foundations only about 1¾ inches. The difference, 2¼ inches, was due to the compression of the mortar joints in the brick lining, which had not hardened in proportion to the rapid increment of the superimposed weights. There are not the slightest indications of any change in the perpendicularity of the tower. The maximum wind force against the tower would cause the line of pressure to deviate but twenty inches from the normal; hence the increase in pressure upon the soil from the wind would be inappreciable.

JOHN BIRKINBINE.—Both Mr. Schumann and the Club are to be congratulated upon this excellent contribution to our proceedings, and if it were not for the lateness of the hour I should like to see the paper generally discussed. For two years I have urged Mr. Schumann to make public the interesting details of this unique structure, and it is gratifying that he has used the

Engineers' Club as the medium for presenting it. During several visits to the works, while the structure of the dome was being perfected, I was impressed with its novelty and immensity. The design, the electrolytic work, the enormous bronze castings, each commanded attention. The paper of this evening should encourage us not to look at the City-Hall tower in the critical spirit which objects to the position of the thirty-eight-foot Penn statue in its relation to the magnetic meridian. We can view the dome as designed and constructed by a Philadelphia engineer, and the molding of the bronzes and the fitting of the work as having been done by Philadelphia mechanics.

EDWIN F. MILLER.—I would like to add to what Mr. Schumann said about literature that there is almost nothing written regarding the subject under discussion when compared to what there is about bridges. There is practically nothing, and the matter contained in Mr. Schumann's paper is entirely new, and therefore very interesting to me.

MR. SCHUMANN.—In preparing this paper it was my purpose to present data for direct application by the engineer in determining strains in polygonal piers, especially as practically nothing exists upon this subject in the English language. Heretofore, structures of the kind in question were by many classed as indeterminate, but such is not the case, as will be found on perusal of my paper, and as further evidenced by the verdict of Prof. Mueller, of Breslau, who in some of his recent publications classes them as distinctly determinate structures.

THE INSPECTION OF BUILDINGS.

BY BENJAMIN FRANKLIN.

Read March 5, 1898.

THE Building Inspection Law of 1893 has had, in general, a very beneficial effect in this city, not only in raising and regulating the standard of construction, but also in the detection and remedying of serious and even dangerous defects in many of the older structures. Personal experience in its application has been varied, and dates almost from the beginning of the enforcement of the law until the present time. With the exception of the modern steel office-building, every variety of structure has come within notice, even some belonging to later colonial periods. The results of several generations of builders employing different methods and different materials have not only been exceedingly instructive, but so personally interesting as to justify embodying them in this paper. It is not intended to criticize the law or to discuss it, but to enumerate a few points which cause some embarrassment in its practical application.

The first of these is the want of a standard constant.

While the law specifies definite weights to be sustained by floors used for various purposes, giving the "factors of safety" for the different members, yet the most important element by which these results are obtained is left entirely to the professional judgment and honesty of the engineer and architect. When this matter was first brought to my attention, after making as thorough an investigation as possible I concluded that the experiments made by Prof. Lanza were the most reliable, and adopted the constants recommended by him, using with a "factor of safety" of 4, a constant of 750 pounds for spruce, white pine, and hemlock, 1000 pounds for white oak, and 1250 pounds for yellow pine.

A very short experience soon showed that these values are too low, and that where the timbers are sound and well seasoned it is allowable to increase the values of their safe bearing loads by making no deduction for the weight of the floor-members and of the floor itself. As personal judgment entered largely into this method, it is open to criticism; but that the views are correct is shown by the values of the following constants recommended by the Bureau of Building Inspectors of Philadelphia, and which have been now adopted in my own practice:

Hemlock, safe fiber-stress,	900	pounds per	square inch.
White pine, " "	1000	"	"
Spruce, " "	1100	"	"
White oak, " "	1300	"	"
Yellow pine, " "	1600	"	"

Further, the law provides for a "factor of safety" of 1 to 4 for floor-members, and of 1 to 6 for members subjected to direct stresses, as in columns and tension rods. This is on the assumption that the load on a floor is a stationary or steady one; but in some manufacturing work the machines in active operation give a shock or blow which, taken in conjunction with the vibrations caused by lines of pulleys and shafting, is equivalent in effect to a distinct and considerable live load. Such are, for example, heavy stamping and cutting machines and large printing presses. Should there not, under these conditions, be some provision for increasing the "factor of safety"?

Every practical engineer is well aware of the unreliability of the various column formulæ as applied to cast-iron and wood. While discarding such formulæ in my own practice and preferring the use of tabulated experimental data, yet it is one of the embarrassing defects of the law that it has established no standard by which uniform results can be obtained by all.

A physician, a lawyer, or a druggist holding a diploma from a professional school may not be allowed to practice without having his qualifications passed upon by a Board of Examiners, yet the Building Law recognizes any one calling himself an engineer or architect as competent to decide questions of design and construction involving grave responsibilities, without containing in it any clause by which professional qualifications can be ascertained. For the sake of *esprit de corps,* the body of engineers and architects should insist upon legal evidence of proficiency and experience from its members. Moreover, as a matter of justice and of protection to the property-owner and tenant, the law should contain such a qualifying clause.

To illustrate: A few weeks ago I was called upon to inspect a building about to be occupied by a large manufacturing firm. The certificate already posted gave each floor an average strength of 164 pounds a square foot, while by calculation a maximum result of not more than sixty-five pounds could be obtained, a discrepancy so great that I had the figures verified by another firm before a report was made.

Masonry is the most important part of any structure, and it is conceded that the vital part of this is the foundation. It is, however, a matter of extreme difficulty, and frequently an impossibility, to arrive at any of the important data in cases of failure. The engineer who is called upon as an expert needs not only a wide experience in this special line, but must make himself acquainted with every detail and condition, and critically analyze every point. The failures from high winds and from thrusts of roofs and floors are generally shown by the manner of falling, and while these can be taken as the direct cause, yet it is more than probable that there would have been no serious damage if the foundations had not been at fault. Briefly, it can be stated that, in a large majority of cases, the causes can be traced to that part of the structure under ground.

Be sure of the foundations and the foundation bed, and, as a rule, the upper part of the structure will take care of itself. It is this, however, that makes the duty of the inspecting engineer extremely difficult, for not only are poor workmanship and material in foundations and footings hidden, but the character and condition of the bed itself can not be thoroughly known. A bulged, cracked, or overhanging wall, though unsightly, is not necessarily dangerous, but shows a new condition of equilibrium. The question for the engineer is whether such a condition is permanent or progressive. I have seen cracks in the side walls of warehouses near the river front, extending from roof to cellar, wide enough on the upper floors to admit the shoulder, which have been so for at least a generation, during which time the floors had been overloaded to the point of straining. A slip in the foundation, due to an inclined ledge of rock or stratum of clay; a drop in the walls on account of "pockets" in the soil; a break at the junction of two walls or along the vertical line of window openings, due to a want of proper proportioning of the foundation footings, cause defects that are apt to be found in green masonry, but which may not affect the stability of the structure.

To obtain evidence of the movement of masonry from what appears to be a fresh break, any one or all of the following methods can be employed. Paste light paper over the opening, any increase of which will tear it. Drive in a wooden wedge until it is held lightly but firmly, so that upon further opening it will loosen and drop out. A method commonly employed by the masons is to mark a line intersecting the crack at right angles to its axis, and measuring carefully the distance between points cut on each side. Any increase or decrease of this measure taken subsequently will be good evidence of movement. The professional instinct inclines one to taking observations by means of a line and transit from outside bases. Such observations are generally easily made, and give absolute results. Last year I was by these means able to prove that an opening between a stack and an adjacent building was not caused by the settlement of the stack, but of the building—the reverse of what was generally supposed. No careful engineer likes to see portions of the masonry of important structures in tension, and perhaps a safe rule would be to condemn any bulged wall if a large proportion is in that condition. The footings for piers and columns should receive special attention. The loads upon them are concentrated, and while they rarely actually fail, yet cases of settlement resulting in sunken floors and strained members are common. Other sources of defects are the placing of the ends of girders or beams over heads of windows and doorways; also the supporting of heavy walls upon weak girders.

It is the general custom, if columns are used, to have brick or stone piers for the first floor supports, and wooden, iron, or steel for the others. Frequently this is varied by having metal columns replace the brick piers, and occasionally wooden posts are used for every floor. In recent years the use of cast-iron columns in this city has been extremely limited, but in New York and in many of the smaller cities throughout this country they are still utilized quite extensively. Most of the older buildings in Philadelphia employing metal columns of any kind use cast-iron designed in the ordinary round or fluted form, the solid star-shaped or circular section, and even water pipe placed vertically. In the early days of my experience in the inspection of cast-iron columns decidedly unsatisfactory results were obtained. The warped or "sprung" appearance of many carried a suspicion of initial stress, and close examination revealed such varying quality of metal as led to the belief that the experience and skill of the manufacturer ought also to be considered.

The common method of testing a cast-iron column is by making two diametrically opposite borings, the location depending upon the manner in which the column has been cast. The hammer will also aid in detecting flaws and blow-holes, but when borings will frequently show a variation in thickness of $\frac{3}{4}$ of an inch in the walls of the same member, it will readily be seen that no reliable data can be obtained that will give safe results.

An inspecting engineer of wide experience stated recently that he had found it necessary to reject about twenty per cent. of the product of even experienced manufacturers, and that where the maker was inexperienced the amount averaged about fifty per cent. He cited an instance that occurred in his recent practice in which of thirty-nine cast-iron columns supplied for an important structure, twenty-four were condemned. I have thought for some time past that a certificate which gives a definite strength for cast-iron columns is practically worthless, a view which has recently been confirmed by the tests at Phœnixville.

The best material for wooden columns is yellow pine, now very commonly used. Oak was formerly the favorite, and occasionally, in poorly built structures, chestnut and even hemlock have been found. Seasoning cracks are the most common defects in wooden columns, but are easily remedied by iron straps. Careless builders will frequently make uneven bearings, will not plumb properly, and will sometimes allow a column carrying a heavy load to rest upon a beam, or even upon floor joists. When wooden posts in cellars have their ends resting on the ground, the fibers have an opportunity to absorb moisture, and should be examined very carefully, as they may soon rot and serious results follow.

Of the thousands of floors in this city belonging to the various stores, factories, mills, and warehouses, comparatively few are modern, yet nowhere in construction have more rapid improvements been made than in this direction. The steel floor of to-day, light, strong, durable, well proportioned, and nearly fireproof, built after the design and under the superintendence of a structural engineer, is far beyond comparison with the product of the practical builder of only a few years back. The critical part of any floor is that supported by the trimmers of the stairways, skylights, elevators, or any other openings.

Generally the eye can detect weaknesses in these localities by cracks in the plaster or by deflections in the ceiling below. In buildings of considerable depth, in which the adjacent structures will not permit of side lighting, the light from the roof is transmitted through skylights and large openings in the various floors below. As these openings are larger than those of the stairways, they require special attention.

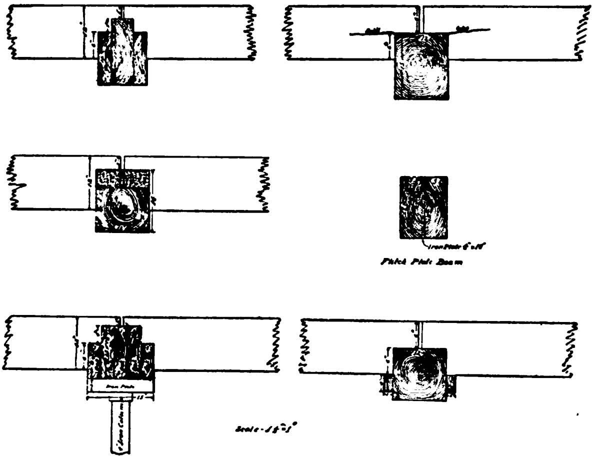
Elevator openings, while having trimmers of shorter span, are liable to increased danger of failure, because the loads passed down them are frequently concentrated on that portion of the floor supported by these members. The use of iron stirrups in securing trimmers greatly increases their strength.

A number of buildings in the older sections of the city have subcellars. They are nearly all badly ventilated and the walls covered with moisture; all woodwork in them should be carefully scrutinized. Posts, corbels, girders, and beams are liable to rapid decay, and need renewal at short intervals. I have seen these members so rotten that a pencil could easily penetrate several inches, and yet the floor above was loaded with merchandise up to the ceiling.

The woodwork of all cellars, however, requires the most rigid and careful examination. Poor ventilation and dampness are favorable to decay, and the ends of joists and beams inserted in the walls rot first. If there is an alleyway or a street adjacent to a wall, so that water can percolate to it, the ends of those members supported on that side invariably rot. Escaping steam or leaky water pipes affect woodwork in the same manner.

In an examination of floor members, the kind of wood is important; but in making a report this should be considered in connection with the use to which a building is subjected. There is a difference of only 200 pounds between the unit strength of hemlock and spruce, but there is a vast difference in their elasticity and ability to resist impact. A floor built of hemlock will not endure heavy shocks. If, then, merchandise is packed in bulky boxes or bales, and piled in tiers, so that when handled it will strike the floor with a blow, hemlock joists will be found split and shattered, where spruce would remain uninjured. When the building is not ceiled there is no difficulty in detecting faulty pieces; but if covered with plaster or light boards the matter is difficult, although suspicious places in the ceiling offer some guidance. When the span is of great length, the cross-girders or joists are supported by longitudinal beams resting upon rows of columns; and it is within the bounds of truth to say that in ninety per cent. of inspections these longitudinal members were found too weak, and sometimes strikingly so. As the supporting girder determines the safe load on the floor, it necessarily follows that to utilize all the material in the cross-members the girder strength must be increased, or this material is a clear loss.

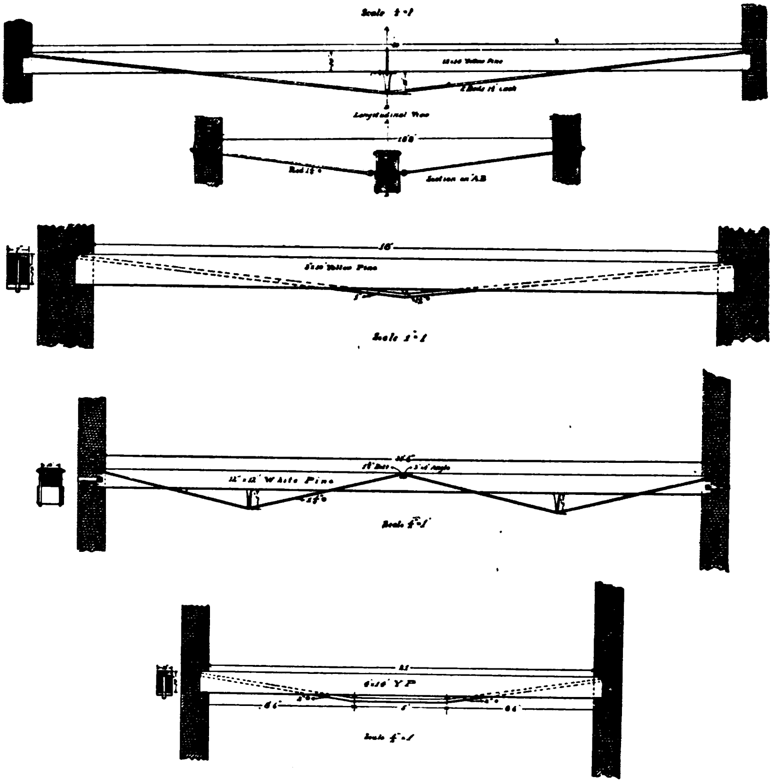
To illustrate: In a recent inspection of a five-story building, the floors of which were 40 feet wide and 150 feet long, 3-inch by 12-inch spruce joints were found resting on a longitudinal girder which was so badly proportioned that 3-inch by 10-inch joists would have given the same floor strength. Had they been used, there would have been a saving of 15,000 feet b. m., which, at $16 a thousand, would have netted the builder $240. Many builders, recognizing this weakness of the main girder, have tried various methods of securing the requisite strength, some of which, taken from my note-book, are illustrated.



SOME OF THE COMMONLY-USED METHODS FOR STRENGTHENING GIRDERS.

One of the most common methods of strengthening a girder is by means of camber rods, used as part of an inverted king- or queen-post truss. In a large number of such cases, owing to the insufficient depth of the camber, the rods are useless, as the girder is stronger alone than the truss of which it forms a part. A few defective trussed girders of this character are shown.

Cast-iron floors are now happily almost obsolete, and the few that are in existence ought to be condemned, if used to bear heavy loads. Where they support "jack" arches, there is little surplus strength left for actual use.



Defective Methods of Trussing Girders.

It was my good fortune once to examine a floor of this character a short time after failure, and which fractured so completely along the wall that I have never felt any confidence since in cast-iron used in building construction.

First-class construction includes such details as the proper bridging of the joists and the anchoring of their ends into the walls.

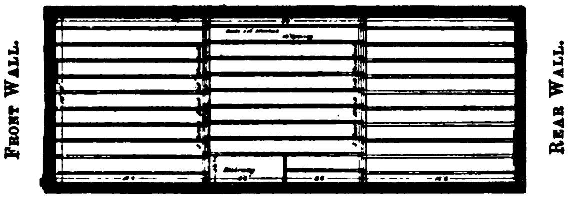
Insurance and building inspectors both agree as to the superiority of open floors, although occasionally their practices conflict in other details.

The proper loading of a floor calls for the exercise of considerable judgment, and also for some knowledge of the principles of its construction. Without some technical training, the amount of safe load to a square foot offers very little guidance in this respect. The manufacturer who pointed out that while his floor strength was guaranteed to be only 100 pounds a square foot, yet he had a machine weighing several tons occupying a base only four feet square, and concluded from this practical test that there was a mistake, only voiced a rather general sentiment. The wholesale clothier who after making a study of his certificate declared he could not apply it, but wanted to know how high he could pile his clothing on tables arranged in a certain manner, illustrates another class anxious to utilize both strength and space, but ignorant of the methods.

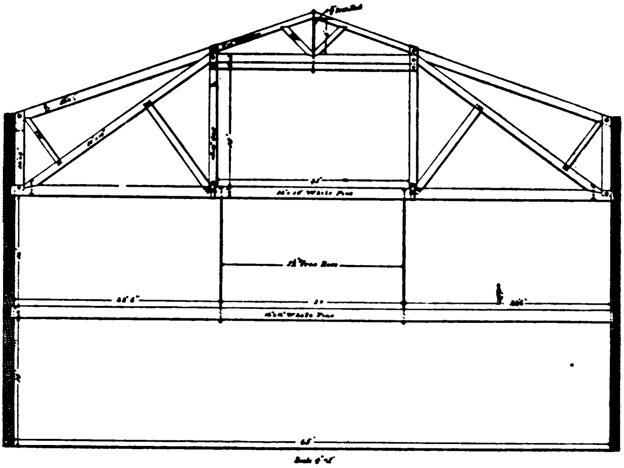
How far information of this character can be given in a general inspection without making a special report is a problem I have never been able to solve satisfactorily, although I have prepared a special form of certificate which meets some of these requirements:

Machines of long bases should to be placed transversely across the supporting floor members, so as to distribute their loads. If heavy, the nearer they are to the walls or columns, the better. Lines of shafting and pulleys should follow the same rule. Hanging shelves, especially if heavily loaded, should be carefully noted, as they place a mortgage on the strength of the floor above. The gearing of machinery itself is important. If it is done in one direction, and the machines are running at the same rate of speed, synchronous vibrations are apt to occur, which may seriously affect the stability of the entire building. Cuts and breaks in the floor, to allow for belting or hatchways, and which have been improperly secured, are other sources of danger.

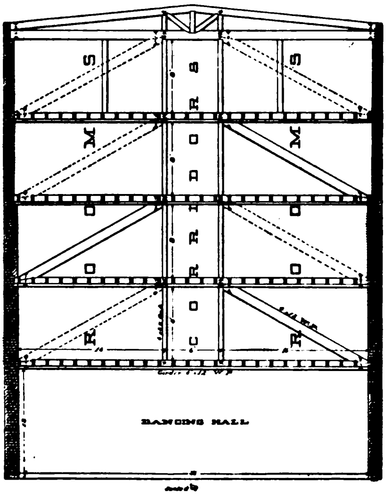
If a roof truss has been properly designed or supported, it is rare that the members or connections will be strained by overloading, even if theoretically weak, if the horizontal pressure has been well considered. All cases of failure of roof trusses that have come within my notice have been due to an insufficient provision for this force. In the older buildings of this city, where the "A" truss was used, this was neutralized by making the front and rear walls heavier.



PLAN OF FLOORS IN OLD BUILDINGS.



ELEVATION OF SUSPENDED FLOOR.



SECTIONAL ELEVATION SHOWING DEFECTIVE CONSTRUCTION CAUSED BY THE REMOVAL OF INCLINED STRUTS OF SUPPORTING GIRDERS.

In theaters, halls, and churches it is best to have the ceilings of the main rooms vaulted, on account of the architectural effect and the acoustic properties. These require specially designed trusses, in which the lower members are brought close to the peak, straining them excessively, and requiring most rigid scrutiny, particularly at connections where weaknesses are likely to develop.

An inspection of a church building with walls 30 feet high, 2 feet thick on lower floor, strengthened every 12 feet by buttresses, showed an overhanging of 7½ inches at the centers, where the sides were not tied in by the end walls. The cause was a badly designed roof truss, 52 feet span, in which all the lower ties, meeting in a point 7 feet below the crown, had given slightly at this joint.

When the truss, generally of an ornamental design, has its horizontal pressure met by buttresses, these should be carefully examined for cause of failure. In the case of a church in which a hammer-beam truss was used, inspection showed that the walls had spread and the floor joists were drawn from their sockets, solely because the architect had used hollow buttresses for ventilating purposes.

Almost every factory carries one or more water tanks on the roof, some of them of enormous weight, which, unless properly secured, are exceedingly dangerous, and have been the cause of numerous accidents. Of the several methods employed to support them, one that appears most open to criticism is that in which the heavy timbers which form the sills of the supporting truss are placed with their ends directly over a line of window openings. Frequently I have seen a number of settlements with window-heads badly disturbed, due directly to this cause.

I wish to note, before this paper is brought to a close, two particularly dangerous conditions, in which inspection and prompt action averted serious loss of life. The owner of a warehouse used for the storage of very heavy goods had acquired possession of a room on the third floor of an adjacent building, part of which was used as a hotel annex. The main floor supports of this room were two hemlock girders, 9 inches by 9 inches, 18 feet long, giving a theoretical strength scarcely more than the weight of the floor, and yet loaded with about eight tons of barreled whisky. The room below was occupied by the hotel proprietor and family as a bedroom and nursery, and, although handsomely furnished, showed a ceiling very badly seamed and cracked. That no accident had occurred was surprising. The other was of a somewhat different character. On the roof of a large manufactory established in this city were placed two large water tanks, each weighing, with contents, about 70,000 pounds. These were placed on a platform, one end of which rested on a 12-inch brick wall and the other on a heavy yellow pine beam, which was supported at the center by a single line of posts running through to the ground floor. On this floor considerable water escaped in the process of manufacture, which, by causing the post to rot at its base and to settle, had thrown the weight of the tank on to the upper girder. This was badly strained, and the tanks had "canted" to a dangerous degree, giving an impression that a fall was imminent. As a number of men and girls were continually employed below the tanks, a failure would have been most disastrous.

In conclusion, I wish to show a few peculiarities of construction which seemed interesting. In nearly all of the old buildings the lower floor-joists are of oak,—now, of course, thoroughly seasoned and somewhat brittle,—while the topmost floor is made of hemlock, laid as shown in the annexed diagrams.

DISCUSSION.

JAMES CHRISTIE.—Taking the relative unit stresses for timbers proposed by Mr. Franklin, I would reduce that for hemlock to 750 pounds. Experiments on straight-grained hemlock do not indicate much inferiority to spruce or white pine. But hemlock is apt to grow with a spiral twist in the fibers, and consequently in the sawed material the lay of the fibers may cross diagonally through a beam. Its resistance to splitting or longitudinal shear is also low. The investigations of the Forestry Division show that the inferior resistance of wet timber is independent of the kind of moisture, whether it is the original sap or water absorbed after seasoning; and as seasoned wood may absorb from five to fifteen per cent. of moisture by a week's exposure, the allowable unit stresses should be lower for exposed than for protected timber. The long-leaved yellow pine is a strong, heavy wood, and entitled to higher unit stresses than the short-leaved varieties; but as it is difficult to distinguish the two varieties apart by the section of the wood, it is not advisable to make a distinction.

So, also, in the classification of oak. The white and live oaks are much superior to the dark varieties, but as the former are less abundant than formerly it is probably safest to prescribe on the assumption that the dark oaks will doubtless be used.

Cast-iron is no longer used for beams, and should not be used for columns in first-class work. The objections to the metal for these purposes are so well known that it is probably safest to prohibit its use except for exceptional purposes. Hydraulic cement is now so cheap and abundant, and its advantages over common lime for mortar so great that its use should be encouraged and the use of lime discouraged by suitable limitations.

JOSEPH T. RICHARDS.—I did not expect to say anything on this subject, but there are a few points I might mention if it would not prolong the meeting. In the first place, I was interested very much in the paper, and I think it a very good one indeed. I have also been interested in Prof. Marburg's remarks. I have, since I was a boy at school, been hoping that there would be some high tribunal to establish the strength of materials. I think it has been a trouble with our engineers that they have not been able to buy any book thoroughly reliable on this subject. The building laws in New York will establish figures for strengths of materials, and Philadelphia and other cities will have theirs. Some of us well remember "Stoney on Strains"; long ago I considered it very good authority. And the ncame Trautwine's book, and I have used it very much; and so many books are presented to engineers, until we are confused to know whether we are right or not. I think Prof. Marburg understands the subject as well as any one I have ever heard speak on it. If the Engineer's Club of Philadelphia, the United States Government, or some good authority would get to work and establish an undisputed standard for the strength of materials, it would relieve the young engineers of this country very much. As to the statement that a foundation is the important part, I find it so in nearly all buildings and bridges that I have had to do with. I find if a stone arch is founded on a rock it seldom fails, whereas if built upon sand and a settlement takes place, the arch breaks and the bridge goes down.

Referring to the use of cement in buildings and bridges, I think we have not mentioned another important matter, and that is the sand. Sand is equally as important as the cement. If the cement is ever so good,—the best Portland, imported, or American,—with sand not pure and gritty, it will never harden properly; therefore I wish to impress particularly the fact that the sand is equally as important as the cement, and should be sharp and clean.

Connecting-parts of wooden or metal structures are also important. I believe engineers are generally capable of calculating the proper amount of metal or wood to go in a column or a floor, but the connecting parts are generally the weak features of a structure. Particular attention should be given to strengthening them up. I find it so in bridges as well as in buildings. Very few bridges have worn out through failure of the main members.

EDGAR MARBURG.—While it is doubtless true that the new building laws have accomplished good results, especially in connection with smaller buildings, yet they are seriously defective in certain important features. Thus, instead of prescribing "safety-factors" of 4 and 6, for beams and columns respectively, the allowable unit stresses should be definitely specified in all cases. It is clearly absurd to base the allowable loads on the "published tables of manufacturers and founders." Not only does this place a direct premium on dishonesty, but, even without intended fraud, there is room for wide differences of opinion in respect to the strength of building materials, especially in the case of materials as erratic in their behavior as timber and cast-iron.

In his reference to timber Mr. Franklin made no mention of the extremely valuable experiments that have been made within recent years, under the direction of Prof. J. B. Johnson, for the Division of Forestry, United States Department of Agriculture. These tests covered some 40,000 specimens, and furnish the most reliable data available on the physical properties of American timber. They served, moreover, to show the unreliability of all previously obtained values, unaccompanied, as they were, by moisture determinations. The importance of the moisture-factor in timber tests was first pointed out by Prof. Bauschinger. These Government tests give a fair indication of the wide range of values to be expected from timbers belonging to the same species. Broadly speaking, the ratio of the lowest to the highest single result in bending varied from about 1 : 2 to 1 : 5 ; this ratio depending, of course, largely on the number of tests. Again, about three-fifths of the values varied more than ten per cent. from the mean result for the same species, and about one-fifth departed from this mean by more than twenty-five per cent. It is to be remembered, however, that these tests were not made on selected material, except in so far as pieces absolutely defective were excluded.

The unit stresses for timber in bending, mentioned by Mr. Franklin as having been adopted by the Bureau of Building Inspection, appear to be too high. It would be more in line with good practice to reduce them by about twenty per cent., especially in the case of yellow pine, it being practically impossible to distinguish the long-leaved variety from inferior ones by ordinary methods of inspection.

It is important to remember, also, that rectangular wooden beams, uniformly loaded, fail usually by shearing along the neutral plane when the span is less than about twenty times the depth of beam. The proportioning of such beams by the common formula for bending, as is almost invariably done in practice, gives rise to errors on the side of danger which become very considerable for short spans.

Our building laws are seriously defective also in that they place no restriction whatever on the use of cast-iron columns. Most engineers will agree that their use should either not be permitted at all or should be confined to buildings not exceeding a height of two or three stories. The building laws not only prescribe no unit stresses for cast-iron columns, but make no provision for the quality of the material and workmanship or the details of construction. The treacherous character of cast-iron columns was never more clearly revealed than in the tests made a few months ago at Phœnixville. Ten columns, taken in part from the ill-fated Ireland building, were tested to destruction. They showed an average compressive strength of little more than half the values indicated by the usual formulæ, notwithstanding the fact that they were centrally loaded, whereas in a building the conditions are far less favorable, owing to the unavoidable eccentricity of loading. The tests on the brackets gave results that were also startlingly low. The danger from eccentric loading was shown in that brackets four or five inches long failed under end loading of about half the magnitude of the ultimate load uniformly distributed. If our building laws prescribed unit stresses for cast-iron columns based on the results of these tests, such columns would quickly pass out of use, to the greater security of our buildings.

In conclusion, I would like to ask Mr. Franklin whether that curious provision of the building laws, requiring the specified loading on beams to be treated in all cases as though it were applied wholly at the middle, is literally adhered to in practice.

COMMUNICATED DISCUSSION.

WM. COPELAND FURBER.—Mr. Franklin's paper is a timely one, and opens up a valuable opportunity for a discussion. The laws of any community on the requirements and limitations of building construction within its jurisdiction should provide, *first*, for safety; *second*, for economy; and should be framed so that after providing for these essentials the designer is left free to construct as his experience and ability dictate. While this proposition is easily stated, it is not so easily carried out. The building laws of many of the cities are cumbersome, inefficient, and inadequate, and frequently hamper the designer, and in many instances discourage the better construction.

Some years ago, in a discussion on a paper on the building laws of Philadelphia, read before this Club by Mr. Frederick H. Lewis, I recommended the establishment of a code of building laws prepared somewhat after the manner of Theodore Cooper's "Specifications for Bridges." Such a code would, of necessity, be more comprehensive in scope than the above-named specifications, in order to embrace the greater number of materials considered by it. Yet with a code of this kind the work required of the designer by the community would be defined, and the laws, if intelligently framed, would lead to better construction and better architecture, and would develop a set of men who would have to understand the fundamental laws of statics and of structural design.

The building laws of Philadelphia contain many grave defects, which might be pointed out at length, but as this discussion has taken more the trend of a discussion of the material of construction and not the theory of design, I will confine myself more to this phase of the subject.

Cement.—One of the most important points touched upon in this discussion is the use of cement in the place of lime. With the natural cement of the Lehigh Valley at our doors, there is little, if any, justification for the use of lime-mortar in building. "Natural" cement, or, as it is sometimes called, "Rosendale," can be laid down in Philadelphia in car-load lots, in bags, at a cost of less than seventy-five cents a barrel, delivered at the building. This cement, with three parts of good sand, makes a strong, reliable mortar at a cost but slightly in excess of lime-mortar. Many of the Philadelphia architects and builders do not seem to know how greatly Philadelphia is favored in this respect by the closeness of the Lehigh Valley cements to the Philadelphia market, nor of their low price. Some Philadelphia architects still specify the New York Rosendale cements, which are not so good and cost more on account of the freight.

Lime-mortar is not a suitable material to use, in these days of quick building. It is impossible to predict its time of setting, and its strength is an element which it is hard to determine. In the olden times, before $50 to $250 a day penalty clauses were common in specifications and buildings were of no great height, lime-mortar answered in place of something better, but the low price and reliability of the modern "natural" cements puts lime out of the list of safe and economical building materials.

Building-lumber.—Some criticism has been made of the suggested unit strain of 1600 pounds per square inch for yellow pine and references have been made to the great variation in the strength of such lumber, and, while there is no question as to these facts, yet yellow pine is the most valuable building lumber at our disposal, and is deserving of our careful consideration. In my experience I have found that its strength and weakness are apparent upon inspection. Fairly straight-grained lumber, free of knots and dry, has a modulus of rupture of 10,000 pounds and above per square inch. It is very stiff and yields but little laterally before rupture. The short-leaved pine is but slightly inferior in strength to the long-leaved, but lacks the same stiffness; it therefore can not be strained so much as the long-leaved. The short-leaved pine is generally more knotty and not so straight grained.

If a unit strain of 1500 pounds or more per square inch is to be used for yellow pine lumber, the specifications should be prepared somewhat in this manner: "The lumber shall be long-leaved yellow pine, reasonably straight grained and entirely free from shakes or cracks or knots exceeding an inch (?) in diameter. No knots will be passed in the upper or lower sections of the middle third of the beam. Knots, if any, must be sound, and small compared with the section of the beam, and confined to the line of the neutral axis. Knots in the outer ends must not be numerous enough to decrease the shearing strength below the safe limit."

Yellow pine furnished under these specifications will, of course, cost more than the average run of lumber, but it is well worth the difference in cost.

Some time ago I had occasion to design the floor system for an extensive store-building and warehouse, in which the requirements were a live load of 200 pounds per square foot and a floor of minimum depth. The spans were approximately thirteen feet. Two-by-twelve yellow-pine joists were used with a fiber-strain of 1700 pounds. The lumber was taken up under the above specifications. Subsequent full-size tests of thirty sticks of this lot of lumber confirmed the correctness of this design, the modulus of rupture of the accepted material running from 8000 to 11,000 pounds.

I believe that, under proper specifications, embracing fully the requirements, and under careful inspection, yellow-pine lumber can be safely used at comparatively high unit strains with economy, even if such lumber costs somewhat more than market prices. The full-size tests here referred to were found to agree very closely with Lanza's tests. The results were placed before the Club several years ago with photographs of the sticks tested. In some full-size tests of hemlock, made at the same time, its utter unreliability was proved by the breaking down at a low fiber stress of dry, straight-grained sticks, apparently sound, and the better performance of apparently inferior material under greater loads. Some sticks of spruce were also tested, but it was found impracticable to break them, owing to the fact that they yielded laterally before rupture. All the sticks in question were tested on a Riehle testing-machine, 12-foot clear span, the ends confined in vertical slots and a 6-inch bearing block at the center of the beam, under the screw of the machine. Since making these tests I have had a very great respect for yellow pine.

Cast-iron Columns.—The use of cast-iron columns in building construction, as has been pointed out, finds little favor with intelligent designers. The practical impossibility of making efficient connections and providing for eccentric loading, in addition to their well-known unreliability, places them outside of the list of safe and economical building materials, and in my judgment the building laws should forbid their use, except under such conditions as will prevent a possibility of their being overstrained, which provision would, of course, exclude their use.

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MODERN HIGH EXPLOSIVES.

A TOPICAL DISCUSSION HELD MARCH 19, 1898.

NATURE AND MODE OF ACTION OF HIGH EXPLOSIVES.

LOUIS Y. SCHERMERHORN.

ABOUT twenty years ago I was engaged in the removal of rocky reefs obstructing the entrances to harbors on Lakes Superior and Michigan, and during the progress of the work large quantities of dynamite were used; I therefore have some practical knowledge of that variety of high explosive, and in the absence of other speakers, and pending the arrival of those who are expected to take part in the discussion, I will open the subject under consideration. It is hoped that some of our members will later present the chemistry and physics of high explosives.

Explosives are divided into two classes—viz., low and high explosives; the former are mechanical mixtures, the latter are chemic compounds. The low explosives consist of a combustible body mixed with a supporter of combustion. The gunpowders known as black, brown, prismatic, and smokeless belong to the first subdivision. In this class of explosives chemic decomposition, and the consequent evolution of large volumes of gases, is accomplished by the rapid burning of the combustible body, through ignition transmitted from one particle of the powder to another.

High explosives are compounds in which both the combustible body and the supporter of combustion are joined in molecular union, forming explosive molecules in which the elements are so slightly and delicately held together that they can be disrupted by even a sudden jar. This disruption allows the elements of the compound to rush into new combinations, resulting in the formation of gases, which, when allowed to expand, occupy an enormous volume when compared with that of the original explosive; or, when confined, exert enormous pressure and disruptive force. Nitroglycerin, guncotton, and their various modifications are types of the high explosives.

Nitroglycerin is formed by the action of nitric and sulfuric acids on glycerin, and guncotton by the action of the same acids on cotton or other forms of cellulose. The constitution of nitroglycerin is $C_3H_5(NO_3)_3$; and of guncotton, $C_{12}H_{14}(NO_3)_6O_{10}$. The nitro-groups are the unstable factors in these compounds, and a slight disturbing force brings about their dissociation in the explosive molecule which they help to form and permits the union of the liberated oxygen with the carbon and hydrogen, producing gases of large volume at high temperature, and consequently high tension.

Nearly all the other high explosives of this class are compounds or variations of nitroglycerin and guncotton. Among these, *explosive gelatin* ranks as that having the highest explosive power. It is obtained by dissolving ten per cent. of guncotton in ninety per cent. of nitroglycerin, gently heated in a water-bath; a small amount of gum camphor is added to reduce the sensitiveness of the compound.

There is still another class of high explosives, known as the fulminates, which are also unstable compounds, probably different in their constitution from those above referred to, the elements of the explosive molecule being sometimes even more delicately held together than in the preceding class. These fulminates detonate under a jar, scratch, or light electric spark. Some are so exceedingly explosive that they are only known in the laboratory, and are so sensitive that they explode through the gentle concussion produced by a drop of the fulminate striking the bottom of the cup when slowly sinking through the oil or water in which the drop of fulminate floats. The less sensitive fulminates, such as mercuric fulminate, are generally used to detonate the nitroglycerin and guncotton compounds.

From what has been already stated, it is seen that the greater effectiveness of high over low explosives is due to the greater rapidity with which the decomposition of the former occurs. In comparing the explosion of gunpowder with the detonation of nitroglycerin or guncotton, the former may be said to burn rapidly, while the latter is instantly resolved into gases by detonation. To illustrate: the complete explosion of a confined cartridge of gunpowder encircling the earth would require nearly a week, while the detonation of a similar cartridge of nitroglycerin or guncotton would be accomplished in about one hundred minutes.

Dynamite, which is one of the commonest forms of high explosives, is simply a mixture of nitroglycerin with an inert absorbent, such as sawdust, wood-pulp, infusorial earth, or similar suitable material. The object of the mixture is to diminish the sensitiveness of the nitroglycerin to the effects of shock, and to facilitate its transportation and handling. No. 1 dynamite contains seventy-five per cent. of nitroglycerin and twenty-five per cent. of absorbent. In this form a cartridge of dynamite may be ignited by a match, when it will simply burn, with the emission of a dense smoke. In the mining districts the burning of a cartridge of dynamite while held in the hand was a favorite method adopted by agents selling the material to demonstrate to users the safety of the explosive. It is needless to state that the inferences from such instruction were generally expanded until the pupil was laid at rest, through a premature explosion brought about by the theory that dynamite was as safe as cornmeal to handle.

Dynamite freezes at a temperature of about 45° F., in which condition it can not be exploded by any means if in compact form, but can be exploded quite easily if loose. It is most effectively exploded when in proper condition by the initial explosion of a fulminating cap or fuse. Although the only explosive element in dynamite is the nitroglycerin, it has been demonstrated that the explosive energy of a pound of nitroglycerin, when compared with an amount of dynamite which contains an equal weight of nitroglycerin, is nearly twenty-five per cent. less than that of the dynamite. The only explanation which has been offered for this anomaly is that the porous character of dynamite permits a more complete permeation of the mass by the disruptive force of the initial explosion, thereby producing a more complete detonation of the explosive.

The relative energy of explosives has been assumed about as follows:

Gunpowder,	=	1.
Nitroglycerin,	=	4.
Dynamite,	=	5.
Guncotton,	=	5.
Explosive gelatin,	=	6.

All such comparisons must be accepted as rough approximations, since the same explosive under apparently similar conditions gives discordant results. This probably arises from the fact that the same explosive compound varies somewhat in its exact constitution according to the purity of the materials used in its formation; and, again, exact measures of the forces developed by explosives are impossible. It has been calculated that one pound of nitroglycerin develops about 1100-foot tons of potential energy. Compared with one pound of coal, which has a potential energy of about 5000-foot tons, there is a marked contrast. On this point it has been suggested that the explosive has to expend a large amount of work in converting its condensed oxygen into gas before it can combine with the combustible elements of the explosive.

The *rationale* of the detonation of explosions is not well understood. That it is not solely due to heat is evidenced by the fact that it is possible to detonate wet guncotton; and from the phenomena of sympathetic explosions, which will be referred to later, it would seem that detonation may possibly arise from the vibratory action of the detonating agent upon the molecules of the explosive. The elements of the explosive molecule are retained in stability by delicately balanced forces; and if these forces are thrown into changed vibrations by an external force, such as the sharp initial explosion of a fulminate, the molecules of the explosive are broken up, and detonation follows.

It is known from experience and observation that the energy of a high explosive depends somewhat upon the character of the initial detonation by which the main explosion is secured. One ounce of gunpowder, even when strongly confined, exploded in contact with guncotton, only inflames it, while ten grains of confined fulminate of mercury produces a full explosion of the guncotton. Forty-five grains of fulminate exploded unconfined only inflames guncotton. Quite large quantities of dynamite detonated in contact with guncotton only disperses it, while a small amount of dry guncotton detonated upon a mass of wet guncotton produces a perfect explosion.

That the energy of explosion depends upon the nature and force of the initial explosion is probably true of all explosives, including gunpowder. A too low initial explosion will simply produce a rapid burning, instead of a detonation of the explosive. Through a defective exploder I have seen one charge of dynamite out of a large number simultaneously exploded under water simply burn, with the continued violent boiling of the water over the charge for several minutes. It is evident from experience that an initial detonation of at least a definite intensity is required to obtain from the explosive its maximum effect. With an insufficient initial explosion combustion ensues, while with a sufficiently large initial explosion complete detonation results.

As guncotton is exceedingly inflammable, this material, with the exception of small quantities, is generally kept wet. The wet gunCottton can be efficiently exploded by the initial explosion of a small quantity of dry guncotton, in which the fulminating cap is exploded. As a protection against the premature explosion of nitroglycerin, it is frequently kept, until required for use, in a congealed or partly frozen condition, which occurs at about 45° F.

The detonation of high explosives is generally obtained through the aid of electricity, by which a fulminating cap or fuse, containing about twenty-four grains of mercuric fulminate, is initially fired in the explosive. By this means a certainty of fire is secured, and when, as in blasting, a number of holes are to be fired at the same time, an increased efficiency is secured by the simultaneous discharge of all the blasts at the same instant. In the removal of Flood Rock, East River, in 1885, 150 tons of explosives were fired by this method at the same instant.

The high explosives are subject to sympathetic explosions; that is, explosions of detached quantities of the material through the detonation of adjacent explosions. The claim has been made that gunpowder has exploded sympathetically, but the cases referred to have not been sufficiently free from other possibilities to render the claim clear of doubt. I have exploded in the open air a cartridge of dynamite that was removed five feet away from the cartridge that was initially fired. At another time a sympathetic explosion occurred that barely escaped being disastrous. It had been the practice to drill, and subsequently charge and fire, twenty-five holes simultaneously; these holes covered an area about twenty-five feet square, arranged in five parallel rows, with five holes in each row. The electric battery became somewhat impaired, and had strength enough to fire only five holes at a time. The whole twenty-five holes were loaded with dynamite, but exploders were only placed in a single row of five holes; after this row had been fired exploders were placed in the next row and fired, and so on until the five rows were completed. This method had been followed daily for more than a month, and on each occasion only the holes had exploded which contained the exploders.

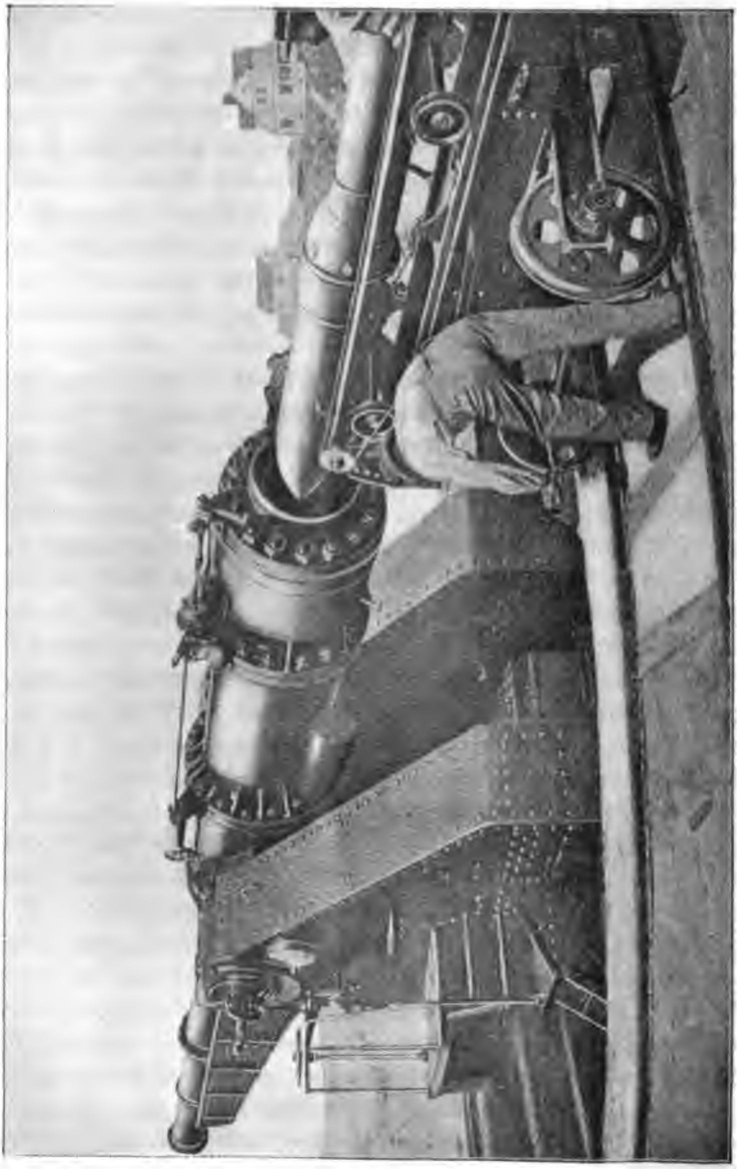
Upon the occasion of the sympathetic explosion referred to, with the explosion of the customary single row of five holes the entire five rows exploded, nearly wrecking the whole plant. Although subsequently the previous method of loading and firing was continued, under precautionary measures, the sympathetic explosion of the remaining charges never again occurred. No conditions surrounding this case of sympathetic explosion were, so far as I could determine, in any way different from those that preceded or followed. I believe that this class of explosions will occur at greater distances in water than they would in the air. In these sympathetic explosions may be found a suggestion bearing upon the phenomena of detonations by the explosion of an initial explosive. In the removal of Flood Rock, in the East River, this principle of sympathetic explosion was utilized. The 300,000 pounds of high explosive used were divided into 13,150 separate charges, of which only 590 charges were connected with the firing battery, the remainder of the charges being so arranged as to explode sympathetically. The results of the experiment indicated that, as was anticipated, the sympathetic explosions had been complete.

The effect of all explosives is increased by their being surrounded with a resisting medium. In blasting operations water is the most efficient tamping that can be used. Experience indicates that there is no gain in efficiency by a submergence of the high explosive to a depth greater than six feet.

A peculiar interest adheres at the present time to the outside action upon the hulls of vessels of high explosives submerged in the water. Some years ago the English Government instituted a series of experiments to determine the greatest distance at which destructive effect could be produced by the discharge of guncotton incased in torpedoes. It was found that at a horizontal distance of 50 feet, with a submergence of 40 feet, 500 pounds of compressed guncotton could be exploded without serious injury to the construction of an iron vessel. At a horizontal distance of 30 feet, and the previous submergence, the iron hull was so crippled that the vessel was in a sinking condition. From this it would appear that submarine mines of limited capacity must be exploded quite near a vessel to produce destructive effect.

The severity of the shock produced by the explosion of comparatively small quantities of a high explosive is indicated by the earth waves which are induced. The explosion of 200 pounds of dynamite on Long Island could be detected 5 miles distant from the explosion, with a velocity of transmission through the earth of about one mile per second. With the explosion of 20,000 pounds of dynamite the earth wave at a distance of 8 miles from the explosion had a velocity of 8300 feet per second, and at 13½ miles a velocity of 5300 feet per second. With explosions occurring in water, an observer placed at some distance therefrom on land, and in close proximity to the water, will plainly hear three distinct and separate detonations; the first transmitted through the earth, the second through the water, and the third through the air.

In closing, I desire to call attention to a peculiar phenomenon which I witnessed at the rock-cut of the Drainage Canal, near Chicago. The final bottom, in a rock-cut about 16 feet deep, was being made by the removal of a depth of cutting of about 6 feet. The material was a close-grained limestone. By the use of a channeling machine the rock to be removed had been previously cut off vertically from the sides of the excavation. The face of the rock to be removed was nearly vertical. A row of holes quite near together had been drilled in a straight line across the cut, parallel with and about 6 feet back of the face. After the holes were loaded with dynamite they were simultaneously fired by electricity, throwing off a mass of rock back to the line of holes. After the blast examination showed a plainly defined crack extending entirely across the cut, nearly parallel



PNEUMATIC GUN.

with and about 6 feet back of the line of holes which had been fixed. The foreman in charge of the work said that this crack appeared after each blast.

The explanation which I offer for this is as follows: At the moment of explosion the rock in front of the row of the holes was thrown forward, and was accompanied by an equal reactive force backward upon the solid rock, by which the solid rock was subjected to an enormous strain of compression. This instantly disappeared, and the elasticity of the compressed rock was brought into action, which in turn exposed the rock to tensile strain, under which it gave way along the line of the crack observed. It is noted in this connection that the tensile strength of oölitic limestone is as low as 200 pounds per square inch, and that a tensile strain of less than 50,000 pounds per square foot would have been sufficient to tear such rock apart along the line indicated.

SOME APPLICATIONS OF HIGH EXPLOSIVES IN WARFARE.

ARTHUR FALKENAU.

The range of destructiveness of high explosives to which Mr. Schermerhorn has referred is of the utmost importance in considering the value of aerial torpedoes, such as are discharged by the pneumatic gun. Although the first pneumatic gun built for the United States Government is of eight-inch bore, in all those built since the bore is fifteen inches. The gun can discharge projectiles of full caliber or, by means of a set of runners and a piston which forms the gas-check, 6-inch, 8-inch, or 10-inch subcaliber projectiles can be discharged. This will be readily understood from the illustrations. The runners are held in position by a wire, which is cut just previous to loading, and the piston is secured by light screws, which shear off when the projectile is fired. Both these parts drop away from the projectile as soon as it has left the mouth of the gun.

The 15-inch, 10-inch, 8-inch, and 6-inch projectiles carry respectively charges of high explosives of 500, 200, 100, and 50 pounds.

The zones of danger to first-class armored vessels, as calculated by the formula of General Abbott, are shown for 15-inch, 10-inch, and 8-inch projectiles. This formula (see *Professional Papers*, No. 23, *Corps of Engineers*, 1881, p. 86) for the explosion of a charge of guncotton under water gives as the pressure exerted at a given distance from the center of explosion:

$$P = \sqrt[3]{\left\{\frac{6636(\theta + 135)C}{(D + 0.01)^{2.1}}\right\}^2}$$

in which P = pressure in pounds per square inch.

θ = angle in degrees between nadir of charge and line from charge to target.

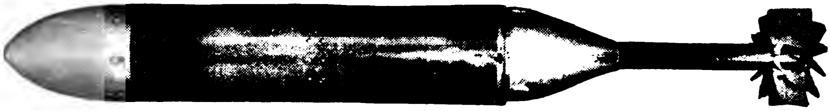
C = charge in pounds.

D = distance in feet.

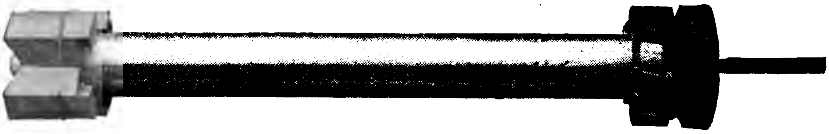
The formula may also be expressed:

$$D = \frac{\left\{6636(\theta + 135)C\right\}^{\frac{1}{2.1}}}{P^{\frac{1}{1.4}}} - 0.01.$$

For first-class armored vessels, the pressure, P, which will destroy them is assumed at about 4000 pounds per square inch.



Full-caliber Projectile for Pneumatic Gun.



Sub-caliber Projectile for Pneumatic Gun.

It is of great interest here to learn how accurately a charge of guncotton can be delivered at the point aimed at by the pneumatic gun. The mechanism of the gun has been greatly improved during the past few years, as a comparison between the Government test made of the guns of the "Vesuvius" in the beginning of 1893 and the test of the guns at Sandy Hook made in the summer of 1894 will show. A few of the most important results are herewith given (*Report of Bureau of Ordnance*, 1893: *Test of "Vesuvius" Guns*):

OFFICIAL DATA OF FIRING FOR ACCEPTANCE OF PNEUMATIC GUN,

At Sandy Hook, N. J., 1894.

Date.	No. of Firing.	Gun.	Kind of Projectile.	Weight of Charge.	Total Weight.	Fuse Setting.	Delay of Explosion.	Elevation.	Initial Pressure.	Loss of Pressure.	Valve Setting.	Range.	Time of Flight.	Force of Wind per Second.		Thermometer.	Barometer.	Humidity.	Remarks.
				lbs.	lbs.			Deg.	lbs.	lbs.	No.	Yds.	Secs.	Feet.	o'clock.	°F.			
Aug. 22.	1	North, or No. 3.	10 in. sub-caliber.	212½	565½	2 sec.'s delay.	2½ sec.	27	1000	256	430	3566	19½	6	9	83	30.22	46	Flight good.
Aug. 22.	2	"	"	214	571½	"	"	"	"	258	"	3560	. .	6	9	83	"	46	"
Aug. 22.	3	"	"	215	566	"	"	"	"	258	"	3575	20	. .	. .	84	"	47	"
Aug. 22.	4	"	"	214	567	"	"	"	"	258	"	3553	18¾	. .	. .	84	"	47	"
Aug. 22.	5	"	"	213½	568¼	"	"	"	"	266	"	3576	19	. .	. .	85	"	48	"
Aug. 22.	6	"	"	215	568	"	"	"	"	268	"	3543	18½	. .	8	85	"	48	"
Aug. 22.	7	"	"	214½	567½	"	"	"	"	269	"	3565	18¾	. .	. .	85	"	49	"
Aug. 22.	8	"	"	213½	568	"	"	"	"	268	"	3567	18¾	. .	. .	85	"	50	"
Aug. 24.	1	"	15-in. full caliber.	505½	1144¾	"	"	34½	"	67	240	1940	17	18.4	5	82	30.24	61	Flight fair; slight gyration.
Aug. 24.	2	"	"	511¾	1146	"	Instantly.	"	"	67	"	1938	17	12.5	5	82	"	62	Flight fair; wobbled toward end.
Aug. 24.	3	"	"	515¼	1152¾	"	2½ sec.	"	"	67	"	1878	17	15.3	5	82	"	63	"
Aug. 24.	4	"	"	503¾	1151½	"	Instantly.	"	"	68	"	1937	17	16 3	5	82	"	64	"
Aug. 24.	5	"	"	525¾	1157	Impact.	"	"	"	67	"	1935	17	16.9	5	82	"	65	"
Sept. 6.	1	8-in. gun, or No. 1.	8-in. full caliber.	. .	. . .	"	"	35½	"	90	275	2618	19	. .	. .	77	. .	. .	Flight good.
Sept. 6.	2	"	"	110½	302	"	"	"	"	74	"	2607	19	. .	. .	77	. .	. .	"
Sept. 6.	3	"	"	. .	. . .	"	"	"	"	84	"	2583	19.2	. .	. .	77	. .	. .	"
Sept. 6.	5	"	"	110	301	"	"	"	"	84	"	2616	19.4	. .	. .	77	. .	. .	"

"The probable rectangles at each mean range attained in the Board's practice, together with the probability of hitting at these ranges a hypothetical vessel of about the size of the 'Philadelphia,' have been calculated, and are given in the appended tables, marked P and Q. In these calculations all but six of the rounds are considered, which were fired with valve-settings taken from Lieutenant Schroeder's range curves; but this, in fact, includes all the shots fired except eleven, part of which were experimental, and part were fired when the 'Vesuvius' was running at high speed. The data for the probable rectangles at the 2000 yards' range are considerably more than for the other ranges; this is owing to the fact that most of the practice had to be made at the longest range in order to exhibit the greater or less reliability of the fuses.

TABLE "P."

"PROBABLE RECTANGLES" AND "PROBABILITY OF HITTING" OF THE PNEUMATIC GUNS OF THE U. S. S. "VESUVIUS," ASSUMING THAT THE UNDER-WATER TORPEDO RUN AND EXPLOSIVE EFFECT OF CHARGE, REGULATED BY PROPER TIME FUSE, EQUALS THIRTY-SEVEN YARDS.

GUN.	NO. OF SHOTS USED IN CALCULATIONS.	RANGE (EXPECTED).	MEAN RANGE.	MEAN ERROR IN RANGE.	MEAN VERTICAL ERROR.	SIDE OF PROBABLE RECTANGLE.	PROBABILITY OF HITTING "PHILADELPHIA" DIRECT (ATHWARTSHIP).	PROBABILITY OF HITTING—TORPEDO EFFECT AND EXPLOSION.	TOTAL PROBABILITY (ATHWARTSHIP).	PROBABILITY (END ON).	TOTAL PROBABILITY (END ON).
I	2	3	4	5	6	7	8	9	IO	II	I2
		Yds.	Yds.	Yds.	Yds.	Yds.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Starboard, .	8	2000	1954	44.75	19.92	118.	.174	.238	.412	.496	.734
" .	4	1500	1491	33.5	12.2	84.1	.242	.318	.560	.50	.818
" .	4	1000	935	59.5	17.6	145.	.170	.186	.356	.457	.643
Middle, . .	7	2000	1988	19.	8.45	46.9	.352	.438	.790	.50	.938
" . .	4	1500	1411	39.	14.	106.4	.219	.216	.435	.406	.622
" . .	3	1000	806	88.	26.	239.6	.137	.130	.267	.368	.498
Port, . . .	5	2000	2024	31.	13.8	79.9	.24	.319	.559	.50	.819
" . . .	5	1500	1354	66.	24.	238.	.137	.169	.306	.43	.599
" . . .	6	1000	898	92.	28.	265.	.114	.125	.239	.35	.475

Length of "Philadelphia" taken as 320 feet.
Beam (mean) of "Philadelphia" taken as 33 feet.
Height of "Philadelphia" taken as 20 feet.
Angle of fall for 2000 yards taken as 24 degrees.

Angle of fall for 1500 yards taken as 20 degrees.

Angle of fall for 1000 yards taken as 16 degrees 30 minutes.

Under-water run taken as 30 yards. Radius of torpedo effect, 7 yards.

Mean point of impact taken at middle of water-line.

Extreme errors are taken as three times the mean error. Lateral errors being very small, are not considered in the competition. The weather was generally clear, light airs and calm.

It has been assumed that the under-water run accompanies every shot.

TABLE "Q."

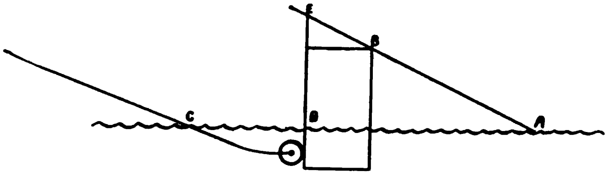
"PROBABILITY OF HITTING" OF THE PNEUMATIC GUNS OF THE U. S. S. "VESUVIUS," ASSUMING THAT NO EFFECT IS OBTAINED BELOW WATER UNLESS THE TORPEDO STRIKES THE VESSEL'S SIDE.

Gun.	Range.	Probability of Hitting Part Above Water (Athwartship).	Probability of Hitting Part Below Water.	Total Probability (Athwartship).	Probability of Hitting (End on—Above Water).	Total Probability of Hitting (End on).	Number of Shots.
1	2	3	4	5	6	7	8
	Yards.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	
Starboard,	2000	.174	.105	.279	.496	.601	8
"	1500	.242	.165	.407	.50	.665	4
"	1000	.170	.118	.288	.457	.575	4
Middle,	2000	.352	.219	.571	.50	.719	7
"	1500	.219	.145	.364	.406	.551	4
"	1000	.137	.081	.218	.368	.449	3
Port,	2000	.240	.148	.388	.50	.648	5
"	1500	.137	.088	.225	.43	.518	5
"	1000	.114	.078	.292	.35	.428	6

Draft taken as 20 feet. Beam taken as 30 feet. Length taken as 320 feet. Height (above water), 20 feet.

Mean point of impact taken at middle of water-line. Lateral-errors disregarded.

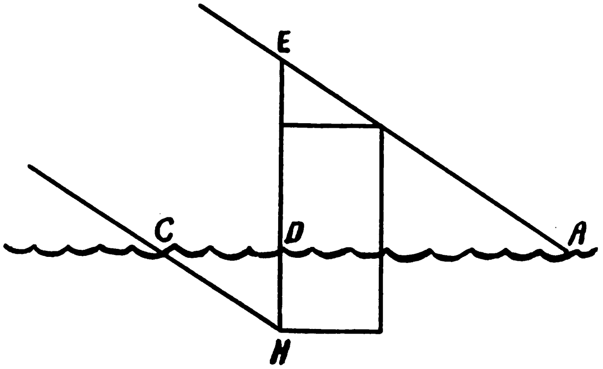
"The probability of hitting at the different ranges was obtained as follows: A vessel of about the length of the 'Philadelphia,' a parallelopipedon in form, with a breadth of 33 feet, height of rail 20 feet, and a draft of 20 feet, was selected for consideration. This breadth is equal to the mean beam of the 'Philadelphia' at the spar deck; the height above the water is assumed to be, roughly, the mean height of the 'Philadelphia's' rail, exclusive of bridges, funnels, etc., while the depth is 2 feet less than her draft. The danger spaces of this target were then assumed to be as shown in the accompanying figure, supposing the vessel to be placed at right angles to the plane of fire. Let A be the angle of fall, B the highest part of the vessel that can be hit by the projectile, and C the furthest point at which a projectile entering the water can, by its combined under-water run and mine-power, damage the ship, provided the 'delay action' time-fuse burns throughout this run. Suppose the mean point of impact to be D, then the



probability of hitting above water will be obtained on the vertical target D E, while the probability of hitting due to the under-water action of the torpedo will be obtained from the space C D. As before remarked, this latter space was assumed to be 37 yards at all ranges.

"The probability of hitting, as above, at the different ranges at which the Board held its practice, will be found in the appended table, marked P; the probability of hitting above water in column 8, under water in column 9, and the sum of these, which is considered the total probability, in column 10. The length of the under-water run adopted is based upon the assumption that the 'delayed action' fuses used in the torpedo will work properly. If, however, it be considered that this fuse will not work, and that we may be compelled to depend upon a simple percussion plunger only, the probabilities of hitting for the different ranges have been computed from the following considerations:

"Supposing, as before, that the plane of fire is perpendicular to the direction of greatest length of vessel, it has been noticed always that when the projectiles plunge beneath the surface of the water they seem to run for a moderate distance at about the angle of entrance, and it is considered that so long as they strike the water within fifteen yards of the vessel's side at the longer ranges and within twenty-two yards at the shorter ranges, the torpedo is about certain to strike the vessel's bottom and to explode by percussion, provided an ordinarily efficient percussion fuse is used. Therefore the vertical target upon which the probability of hitting should be computed, in this case, would be E H, A being the angle of fall, D H the draft, and C D the distance within which it is assumed that the projectile must strike the water in order to reach the vessel's bottom by direct impact.

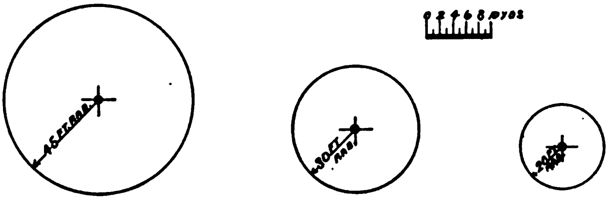


These results are included in the table appended, marked Q; and it will be seen that, even when the under-water run is thus restricted, the target presented by the ship's side is a good one, and the probabilities of hitting are very fair.

"In both these tables the vessel is also considered as being presented longitudinally to the line of fire, and in this case the probability of hitting is, of course, considerably greater. In all the practice, the lateral deviation has been observed to be very small, and has consequently been disregarded in computing the probability, and it will be observed that in the tables the lengths only of the rectangles are given."

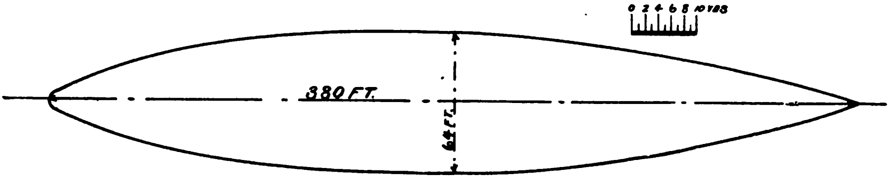
The figures on page 110 are plottings of some of the shots fired in the testing of pneumatic guns at Sandy Hook and given in the above tables, together with their zones of danger. The plan of the U. S. S. "New York," drawn on the same scale as the plotting of the shots, will give an idea of the danger a vessel would run coming within range of the pneumatic gun.

According to table P, the probability of hitting a vessel like the

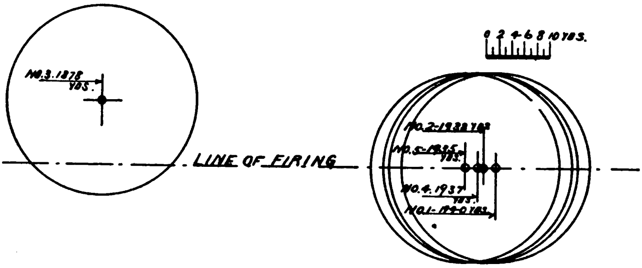


Full caliber (15 in.) Sub-caliber (10 in.) Sub-caliber (8 in).

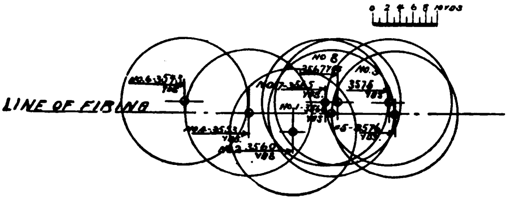
COMPARATIVE AREA OF DANGER-ZONES.



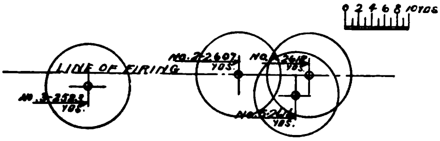
U. S. CRUISER "NEW YORK."



Full caliber (15 in.)



Sub-caliber (10 in.)



Sub-caliber (8 in.)

DANGER-ZONES PLOTTED FROM ACTUAL FIRING.

"Philadelphia" by projectiles from the middle gun of the "Vesuvius" athwartship is 79 per cent. and end on 93 per cent. at about 2000 yards. The percentage of risk to the "New York," which presents a larger target, is proportionately greater.

The illustrations on the next page show the blowing up of the schooner "Silliman," in New York harbor. The experiment was made with an eight-inch gun mounted at Fort Lafayette. The projectiles contained 55 pounds of nitrogelatin. The wooden schooner was 90 feet in length, anchored bows on at a distance of 1884 yards from the gun. The first round fell short; the second exploded close to the target, broke off the mainmast, and injured the stern deck; the third exploded directly underneath the vessel and broke it up completely.

The improvement in accuracy of fire with the Sandy Hook guns will be more readily appreciated by making the calculations for mean ranges and errors, which give the following results:

August 22, 1894.	Eight shots.	Mean range,	3563	yards.
		Mean error,	3	yards.
August 24, 1894.	Five shots.	Mean range,	1925	yards.
		Mean error,	19	yards.

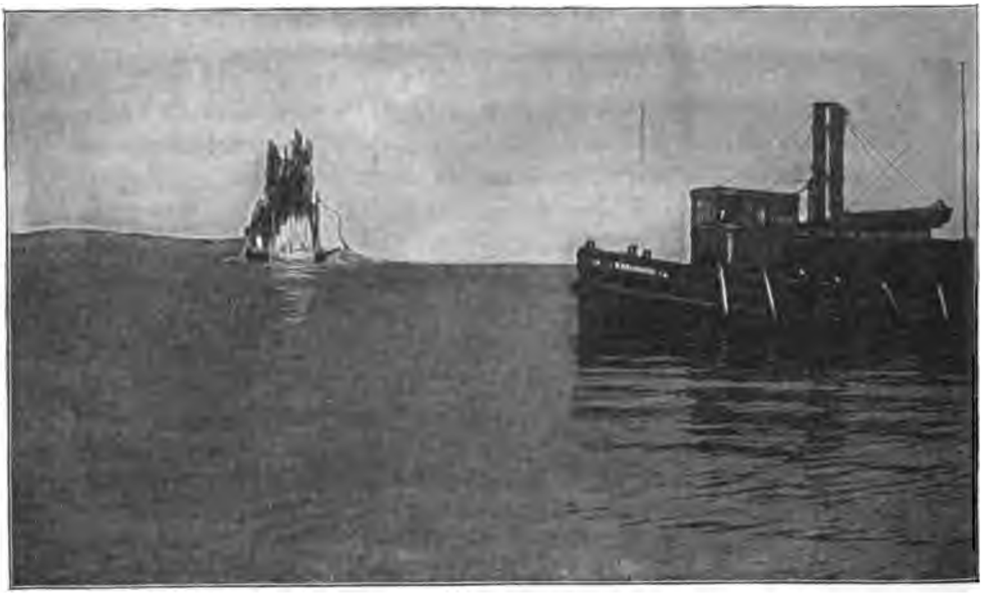
If shot number three, which fell considerably short, is omitted, we have:

August 24, 1894.	Four shots.	Mean range,	1937	yards.
		Mean error,	1.6	yards.
Sept. 6, 1894.	Four shots.	Mean range,	2606	yards.
		Mean error,	11	yards.

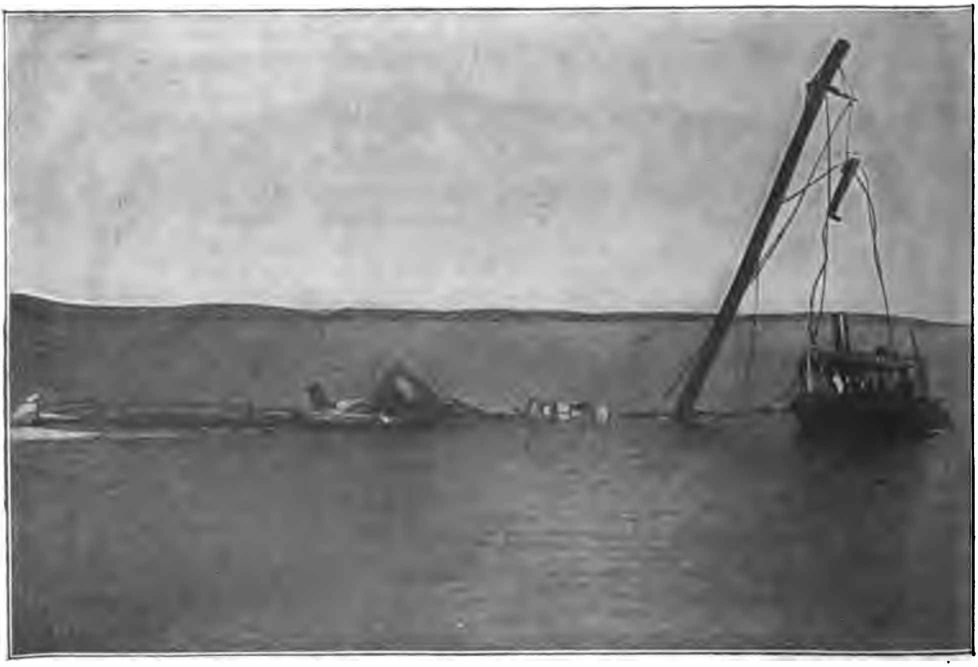
The Government specification for the test of the guns placed at San Francisco in 1895 required that the proportion of hits at all ranges in a rectangle 360 feet in length by 90 feet in width must not fall below 34 per cent. In the actual test 75 per cent. of the shots fell within this rectangle.

The test of the guns of the "Vesuvius" in 1893 was considered sufficiently satisfactory by the Board to warrant it in stating that the guns would be of decided value in naval warfare if the fuses could be made reliable. In these tests the fuses practically proved a failure.

That this difficulty has been entirely overcome is evident from the fact that out of 38 shells fired at the Sandy Hook test, only two



Third shot.



Effect of third shot.

DESTRUCTION OF THE "SILLIMAN."

failed to explode, and at the San Francisco test none failed. As a result of the "Vesuvius" tests it was found that the admixture of potassium chlorate with mercuric fulminate prevents proper detonation.

The fuse known as a trigger-fuse is inserted at the point of the projectile. At its base is a cylinder, 12⅜ inches long by 3 inches in diameter, which contains the priming charge of 2¾ pounds of dry guncotton. The detonator consists of a small copper cylinder containing 37 grains of mercuric fulminate, and extends into the dry guncotton charge. In front of the detonator is some fibrous dry guncotton, which is ignited by a train of flash-powder, either directly, or the powder in the flash-channel is ignited by a slow-burning powder composition in a time-channel. There are three distinct methods of exploding the detonator.

First.—If the projectiles strike a slight resisting medium, such as water or loose sand, two spring-actuated hammers are released which fire caps, held on nipples, the holes in which communicate with the time-channel. Normally, the hammers are held cocked against the force of springs by a metal ring, the inertia of which causes it to free the hammers when the body of the projectile is retarded. In this case the shell will explode a specified time after striking the water.

Second.—If the projectile strikes point-blank against an unyielding solid, the crushing in of the head at once causes the setting off of a cap which communicates directly by a flash-channel with the fulminate detonator, thus causing instantaneous explosion.

Third.—If the projectile strikes a glancing blow against an unyielding solid, the powder in the flash-channel is set off by caps struck by one or more of eight little hammers set in a circle around the fuse, thus causing instantaneous explosion. These hammers are controlled by springs stiff enough to prevent them from performing their function when striking the comparatively lighter glancing blow on the water.

Various experiments have been made to fire these powerful and sensitive high explosives from powder-guns, but thus far no satisfactory results have been attained; in several instances the shells have exploded within the bore of the gun. It must be remembered that the initial pressure of the gases due to the explosion of gunpowder in a modern gun is about seventeen tons per square inch, while the initial pressure that is never exceeded in the pneumatic gun is only

1000 pounds. The energy imparted to the projectile by the pneumatic gun, and hence the range, can be varied by setting the controlling valve for any desired cut-off, or the initial pressure may be varied at will.

The method of projecting large charges of high explosives here described seems to possess many advantages over systems previously in use. The limit of range of Whitehead torpedoes is only about 500 yards. Subaquatic torpedoes or mines can not be used to advantage for the protection of deep channels.

An additional use to which the dynamite gun can be put is the destruction of fixed submarine torpedoes by causing sympathetic explosions of the latter, and thus clearing an enemy's harbor. It is of further interest to note that the report of the gun is very faint and that there is no smoke, facts which under certain conditions must prove of great value.

GENERAL DISCUSSION.

E. M. NICHOLLS.—I think the observation in regard to blowing down is one that many practical men will bring forward promptly. In blasting hard pan I have had to use a great deal of dynamite, and I found if we had a dry bank on top and went down to where it was soft we did not have much effect; but when it was of uniform consistency for any depth we got the effect at the bottom, splitting it off in the way spoken of for ice; that is, the radial lines. I have had to blast a good many stumps; by putting the dynamite cartridge under the stump in the dirt we did not get much effect; but if we bored the knee a little way and then put in the cartridge, the stump was generally blown out, roots and all. The earth gives way as easily as water does in overcoming the resistance of the explosion. When a solid material is on each side, better results are obtained than when the material is yielding.

JAMES CHRISTIE.—How are high explosives most advantageously used in removing submerged wrecks?

MR. SCHERMERHORN.—If a wooden wreck is to be removed, cartridges of dynamite are placed by divers against the sides or bottom of the hull and the wreck blown up in sections. In the removal of iron vessels the dynamite is frequently used in sausage-shaped cartridges, which are arranged so as to blow off sections of the iron work by cutting away consecutive parts each time. This cutting effect of high explosives is well illustrated by its use in cutting off timber piles or similar obstructions. A sausage-shaped cartridge, placed around the pile at the point at which it is to be removed, cuts off the pile perfectly.

From experiments which have been made, the pressure required to produce destructive effect upon iron ships has been estimated as high as 6000 pounds per square inch. Under such a pressure, developed by the explosion of a submarine mine or torpedo, plates are driven in, frames sheared and bent, and the vessel completely crippled. Such pressure and effects have been obtained by the explosion of 500 pounds of high explosive thirty or forty feet distant from the side or bottom of the vessel.

The pressures exerted by high explosives under water have been determined by the measured compression of lead cylinders placed at different distances from the center of explosion, and the amount of the resulting compression of the cylinder compared with similar cylinders placed under a measured static pressure. It has been found from experiments made under water that the explosive acts with greater energy on vertical than on horizontal lines. This probably arises from the fact that the force of the explosion moves along the lines of least resistance, and such lines are upward and downward rather than lateral, the vertical lines leading to the surface of the water or to the bottom, while the horizontal lines lead indefinitely into the adjacent water space.

C. H. OTT.—There is within 16 miles of this city a unique establishment for the manufacture of dynamite.

The city of Philadelphia several years ago appropriated a sum of money for the removal of the ledge rock obstructing the channel of the Delaware River at Schooner Ledge. The rock ledge, now in the process of removal, covers an area of 6 acres, the depth to be removed varying from 6 inches to 3 feet, covered by 24 to 30 feet of water. The rock is removed by blasting and dredging. All of the explosives used—from 60 to 300 pounds per day—are manufactured appurtenant to and near the site of the rock.

Upon a scow, about 20 feet wide and 40 feet long, is erected a two-story shanty, in which is installed the apparatus for the manufacture of dynamite, consisting of a small steam-engine and boiler, agitator, washing tubs, and mixing troughs.

The process of manufacture is briefly this: 1500 pounds of mixed acid—950 pounds of sulfuric and 550 pounds of nitric acid—are placed in the agitator in the second story of the factory (the agitator or mixer resembling in construction a large ice-cream freezer), and from 214 to 218 pounds of commercial glycerin is then gradually allowed to flow into and thoroughly mix with the acid. During the mixing the temperature of the mixture is carefully watched and regulated by the use of cold water or ice. A temperature of 60° F. is maintained as closely as possible; 90° F. is considered a danger-point.

Upon the complete admixture of the acid and glycerin, the resulting compound (being about the consistency of starch pudding) is washed from the free acid by ladeling it through a series of tubs filled with water, and is finally washed by hand in small quantities in a copper bucket, the resulting product being about 450 pounds of nitroglycerin.

This is then placed in a mixing trough and thoroughly incorporated with about 150 pounds of wood pulp, and is then slightly compressed into paper cartridges and is ready for use. The cartridges used are 36 inches long and 2½ inches in diameter, and are inserted in drill holes 4 inches in diameter, 3 to 6 feet deep. The charges are not tamped, the depth of overlying water being sufficient for the tamping. The dynamite, as used, is fully 75 per cent. nitroglycerin.

The contractors for this work have stated that they can buy dynamite in the open market cheaper than they can manufacture it, but prefer to manufacture it near the site of the work, as its quality, strength, and evenness can be more easily regulated; also that it can be used freshly made, which has a marked influence upon its effectiveness, and that frequent manufacture and close consumption avoids the greater part of the risk of storage and transportation.

The manufacture of dynamite at this factory is conducted by one man with a helper, who also attends to the transportation of the finished products from the factory to the drill boats, the factory being about a mile distant from the site of the blasting operations.

C. L. PRINCE.—Some years ago I was located near a road that was being built. During the construction it was necessary to blast through considerable rock. I learned one day that there was to be a little explosion, so went there with my camera to see it. The explosion was from 6 holes about 7 feet deep, as far as I recall, and was set off by a battery about one-eighth of a mile away. I climbed a tree about 200 feet away, and strapped my camera to it, so that in case of an accident the view at least might be saved.

When everything was ready I gave the signal to fire, and as I saw the rocks start I "pressed the button," and got a fairly successful picture, the rocks being sharp and clear. At the time the snap was made the rocks might have been 10 or 15 feet high, while the column of dust rose to 25 or 30 feet.

THE ENGINEERING CHEMISTRY OF BOILER-WATERS.

HENRY LEFFMANN.

Read April 2, 1898.

Pure water is an artificial product of the laboratory, and is so difficult to prepare and preserve that its properties can hardly have any practical importance. Natural waters always contain substances in solution and suspension, varying from mere traces to very large amounts. The effects and uses of water are dependent upon the character and amount of the materials present. When the wholesomeness or physiologic effects are to be determined, the important points are the nature and amount of the mineral ingredients and the character of the organic life; but when the applicability of a water to steam-making purposes is to be determined, the action of the dissolved gases becomes important, while the organic matter, living or dead, has no practical importance unless the amount be unusually large or it be exceptional in character. Many other technical uses for water, except that of steam-making, may come under the supervision of the chemist, but they are of less practical moment.

For the study of natural waters it is convenient to arrange them into groups, and although this classification is for use in the determination of the wholesomeness, it will not be amiss to note it. The groups are four—viz.:

Rain-water.—Water precipitated from the atmosphere under any conditions, and, therefore, including dew, frost, snow, and hail.

Surface-water.—All collections of water in free contact with the atmosphere, whether in motion or at rest.

Subsoil-water.—Waters not in free contact with the atmosphere, but percolating or flowing through soil or rock at a moderate distance below the surface, derived in large part, if not wholly, from the rain or surface-water of the district.

Deep-water (artesian-water).—Water accumulated at considerable depth below the surface, from which the subsoil-water of the district is separated by one or more difficultly-permeable strata.

Rain-water collected in the open country is usually nearly pure, but in cities it may contain much objectionable matter.

Surface-water is usually well adapted for boiler purposes, except for its liability to turbidity. It usually contains only a small amount of dissolved solids and but little carbonic acid.

Subsoil-water, which is that obtained from springs and ordinary wells, is usually clear, and contains notable amounts of solid matter.

Deep-water is variable in character, even within a limited area; and at approximately the same depth waters of markedly different characters will be found. Deep-waters are apt to be rich in dissolved solids, but there are many exceptions to this. Iron compounds and sodium chlorid are often present in considerable quantity, sometimes so great as to unfit the water for any household or technical use.

The suitability of water for boiler purposes must be considered with reference to the two properties of corroding and scale-forming. These are, to some extent, antagonistic, since the deposit of material on the iron will, of course, protect it. Experience shows that waters of very high purity are by no means always the best for boiler use. In general, it may be said that the corrosive qualities are due to the water molecule itself or to the oxygen and carbonic acid present in solution. More rarely, we have organic or mineral acids, and these, especially the latter, are highly objectionable. Organic acids of somewhat indefinite character result from oxidation of vegetable matters, especially the cellulose and lignin of wood-fiber; hence, waters collected from swampy regions, in which there is necessarily much decaying vegetable fiber, may contain organic matter in a corrosive form, practically acid, although perhaps not corresponding exactly to the strict definition of that term in modern chemistry.

The water supplied to Sheffield, England, is derived from peaty moorlands, and sometimes has a strong action on iron. In one stage of the flow the acidity is equal to about ½ of a grain of sulfuric acid to the gallon. As these acid-like substances are often not volatile, the concentration of the water in the boiler greatly increases the corrosive action. Even when the organic substances are not capable of acting as direct corrosive agents, they may indirectly determine the oxidation of the iron. The laboratory affords us more than one instance of the formation of a body being promoted by conditions favorable to its combination when formed, and it seems possible that any organic matter which is readily converted into acids by moderate oxidation would be capable, under the joint action of free oxygen and a distinctly positive body, such as iron, of forming a soluble iron salt, although neither the oxygen nor the iron alone would accomplish the action.

An important commercial process may be cited as an example of this: Finely divided vegetable matter, such as sawdust, is readily converted into potassium oxalate by heating with caustic potash; and from this product oxalic acid, one of the strongest acids known, may be obtained. Vegetable matter is not converted into oxalic acid by the action of air alone or mild oxidizing agents.

Some years ago, when studying the Anderson process of purifying water, I had occasion to note an action which seemed to be explicable on this theory. A sample of water was received from the neighborhood of Norfolk, Va. It was deeply colored with organic matter. On agitating it with iron-turnings in a partially-filled bottle for a few minutes, a bulky precipitate was formed, and on filtration a colorless water was obtained, tests of which showed that ninety-seven per cent. of the oxidizable organic matter had been removed. It seems probable that somewhat similar action would occur in a boiler, and that a material corrosion of the iron would ensue, for in the experiment noted above a notable amount of the iron was converted into ferric oxid.

It is hardly necessary here to speak of the injurious action of mine-waters. In most cases they owe their acidity to sulfuric acid derived from the oxidation of pyrites, and exercise a powerful and constant corrosive effect on iron, even in the cold.

I have lately had occasion to examine two waters which have marked corrosive qualities, although they do not show excess of organic matter or marked acidity. They are of somewhat different composition. One contains about six grains of solid matter to the gallon, the other about nine. Their corrosive effect is exerted on other metals than iron; indeed, with regard to both samples, the most serious complaint is that the soldered joints in the lead lining of the flush-tanks are destroyed. One of the samples was sent with the information that everything was corroded except the copper portion of the ball on the valve-rod. This statement led me to suspect the presence of a copper salt, but none was found. Copper and lead salts will prove very corrosive to iron. The quantitative examination of these waters has shown that in both the amount of magnesium and chlorin is high in proportion to the other solids. This suggests the view that the corrosive action is due to magnesium chlorid, as noted below.

The corrosive action of the soluble chlorids on common metals is well known. Practically only sodium chlorid and magnesium chlorid come into consideration. Sodium chlorid is present in almost every sample of water, but in surface- and subsoil-water, unpolluted with sewage, the quantity is usually less than one grain per gallon. In deep-waters the amount is often quite large. Thus, in the well (over 400 feet deep) on Black's Island, just below the mouth of the Schuylkill River, the sodium chlorid exceeds fifty grains per gallon. Such a water would be expected to exert a decidedly corrosive action.

Magnesium chlorid is generally considered a highly objectionable ingredient by reason of its liability to a reaction with water, by which hydrochloric acid is formed. It is known that magnesium chlorid can not be obtained pure by evaporating its solution in water; the residue will contain some magnesium oxid, while hydrochloric acid escapes. The water takes part in the reaction.

$$MgCl_2+2H_2O=MgH_2O_2+2HCl.$$

Some experiments that I have made indicate, however, that this reaction does not occur until the solution becomes concentrated. However, we must bear in mind here the principle that has been stated in connection with the effect of organic matter, namely—that the presence of iron may promote the reaction by offering an opportunity for the action of the chlorin. The experiments of evaporating magnesium chlorid in glass, porcelain, or platinum vessels do not represent the conditions in practice, and the reaction

$$MgCl_2+Fe+2H_2O=MgH_2O_2+FeCl_2+H_2$$

might occur under conditions which would not bring about the former reaction.

To be on the safe side, some chemists have advised that the magnesium and chlorin determined in the analysis should be so expressed as to show the maximum amount of magnesium chlorid that could be produced from the water, and thus determine the upper limit of a corroding effect from this source.

Even supposing we have no substances in the water capable of acting directly on iron, it is not likely that any boiler will escape some corrosion, for commercial forms of metals are not usually homogeneous, and the contact of water containing appreciable amounts of mineral solids will establish a polarization which one portion of the iron will become the positive plate in a voltaic couple and suffer corrosion in consequence.

The gases dissolved in water are usually nitrogen, oxygen, and carbon dioxid; the last is assumed to exist as carbonic acid. Nitrogen is regarded as without effect, but the others are important. Spring-water of high class—that is, containing very little dissolved solids—often produce marked corrosion. Some years ago one of the large trunk-line railroads had much trouble from boiler-corrosion on a division which was supposed to furnish excellent water. The road had a well-equipped laboratory, but the chief of that department assumed that the corrosion was due to free acid. He held to this view stubbornly, and in defense of it had numerous analyses made and considerable volumes of the water evaporated in order to concentrate the acid which was not there. The examination showed that the corrosion was due to the dissolved oxygen, probably assisted by the carbonic acid. The water contained so little scale-forming material that no protecting film was formed on the iron, and hence it was exposed to the direct corrosive action of the water and the contained gases.

The solubility of oxygen in water is greatly diminished by heat, while chemic activity is increased. Hence, the cold water charged with oxygen entering the boiler has this oxygen released from solution and it attacks the iron. The corrosion is, therefore, apt to be most marked at the point at which the feed-water enters. The presence of the free oxygen and its increased activity probably also assists the corrosive action of the carbonic acid. The reaction

$$Fe + H_2CO_3 = FeCO_3 + H_2$$

is unlikely, but

$$Fe + O + H_2CO_3 = FeCO_3 + H_2O$$

is not improbable; indeed, it is supposed to occur in some cases in the Anderson process for purifying water.

When the amount of scale-forming ingredients is sufficient to produce a film on the iron, it is protected from such immediate corrosion, and we are reminded of the conditions which occur in the human mouth—the decay of the teeth and the deposit of tartar are antagonistic conditions and do not occur at the same spot.

Two other influences toward corrosion may be mentioned:

Unpolluted waters usually contain but small amounts of nitrates, but waters drawn from shallow wells in populated districts generally contain notable quantities, probably in the form of calcium and magnesium nitrates. These are corrosive salts, and, as the determination of the nitrogen existing as nitrates is easily made by modern methods, it should not be omitted by the analyst. If the proportion exceeds a few parts per million it should be given consideration.

The fatty oils may lead to the production of corrosive substances. These often contain free acid, and the proportion may be increased in the boiler since high steam decomposes the fats and oils, producing a fatty acid and glycerol. The mineral oils are hydrocarbons and are not subject to such decomposition, and hence are not likely to form acids. In fact they exert rather a reducing action and might restrain corrosion.

Turbid waters should be filtered before being used in boilers. If filters using alum are applied, care should be taken that an excess of alum (or aluminum sulfate) be not used, as decided corrosion might be produced.

The scale-forming ingredients in water are principally the compounds of calcium and magnesium. Usually the amounts of silica and iron are not sufficient to produce marked deposits. Calcium and magnesium exist in natural waters principally in the form of sulfate, carbonate, or chlorid, and the amount and character of the scale will depend, to a great extent, upon the form of combination. Magnesium and calcium carbonates are but slightly soluble in pure water, but are rendered much more soluble by the presence of free carbonic acid. This is usually expressed by saying that the substances form soluble bicarbonates, but the term is little more than a form of words. Whatever be the condition, it is well understood that it is disturbed by the removal or neutralization of the free carbonic acid, when all but the small quantity of the carbonate, soluble in the pure water, is precipitated. In the ordinary use of water, the removal of the carbonic acid is brought about by the heating, and deposits of the carbonates promptly take place. The amount of such deposit is, therefore, independent of the concentration which the water suffers.

Magnesium sulfate is freely soluble in water under all ordinary conditions and need not be further considered. Calcium sulfate is one of the most objectionable ingredients in boiler-water. Although often described as an insoluble salt, it is soluble in cold water to the extent of over 100 grains to the gallon. At the boiling-point it is somewhat less soluble, and at temperatures decidedly above this, say 300° F., which corresponds to about sixty pounds pressure, it is nearly insoluble. Now, it is a well-known principle that insolubility controls chemic interaction. Hence, water containing calcium compounds and sulfates would be expected to form a precipitate of calcium sulfate in such amount as to exhaust one of the ingredients that are needed to form it—that is, until either the Ca or the SO_4 is used up. Possibly, the presence of considerable amounts of chlorids or potassium or sodium carbonate would mitigate this condition, but in most instances, I think, it will be safe to apply the same rule that is given for the estimation of magnesium chlorid, namely,—base the judgment on the maximum amount of calcium sulfate that the water could yield under any condition.

In response to an inquiry, Dr. Dudley has kindly given me an outline of the method used in the Pennsylvania Railroad laboratory at Altoona for the approximate determination of scale-forming ingredients. The total solids are determined in the usual way, the residue is treated with dilute alcohol (fifty per cent.) and the undissolved matter is designated scale-forming material. The method is found to be satisfactory in its application.

Any condition that promotes the insolubility of the calcium sulfate will, in some measure, represent the effect of heat, and hence the amount of precipitation obtained by adding alcohol to the concentrated water will be of value in determining its incrusting tendency.

Although the various materials which deposit in boilers are often collectively designated as " scale-forming," yet as is well-known the different material differs much in the character of the material deposited. The carbonates produce a soft scale, calcium sulfate a hard scale.

Mr. E. F. Smith has called my attention to the fact that some manufacturers at Manayunk, Philadelphia, have been obliged to abandon filters requiring alum on account of the marked increase of hard scale which is brought about. This is easily explained: the alum introduces a notable amount of sulfate into the water. Probably aluminum chlorid could be substituted with advantage in these filters.

In that portion of the deposit in direct contact with the hot iron, the precipitated magnesium carbonate becomes converted by the combined influence of the heat and water into magnesium hydroxid and carbonic acid

$$MgCO_3+2H_2O=MgH_2O_2+H_2CO_3.$$

Hence many boiler-scales show notable amounts of magnesium hydroxid without necessarily indicating that it is due to the decomposition of magnesium chlorid.

Perhaps, at the end of this exposition of chemic principles, you may be inclined to say with the Mikado, "All this is very interesting, but we come upon an entirely different matter." Engineers can not control the laws of nature, and often have no choice of water. The question is then what may be done to remedy the objectionable conditions. Turbidity may be easily remedied by filtration. In the technical uses of water a mere straining effect is needed; the removal of bacteria and the mere opalescent suspended matter is not necessary, hence less care is required in the operation of the filtering apparatus than when sanitary questions are involved. I have already called attention, however, to the danger of the too free use of aluminum salts.

When corrosion is due to free acid it may be easily overcome by the use of alkaline substances, among which caustic soda and soda-ash would be most generally applicable. The corrosion due to the decomposition of the magnesium salt would be benefited by almost any of the methods adopted to prevent scale, which will be considered later. The corrosion due to dissolved oxygen will be materially reduced by heating the feed-water, and also by arrangements for not allowing the water to come directly in contact with any highly heated spot.

The prevention of scale is secured in various ways. The magnesium and calcium carbonates that may be held in solution by carbonic acid are all precipitated by the removal or neutralization of that acid. The former may be accomplished by the heating of the water or even by exposing it in thin layers to the action of air; the neutralization can be brought about by the addition of some basic substance. One of the oldest methods is the addition of slaked lime, calcium hydroxid, which, by converting the carbonic acid into an insoluble carbonate, precipitates both itself and the carbonates in solution. Caustic soda will also accomplish this.

The precipitation of calcium sulfate can not be so easily accomplished. It is soluble in water to the extent of over 100 grains to the gallon. It does not owe this solubility to any other substance, and it is not much less soluble at the boiling-point. If the precipitation is to be accomplished by heat alone, it must be under decided pressure, as exhaust steam will not produce the same effect as it will with dissolved carbonates. Calcium sulfate being a most objectionable ingredient, much attention has been given to the methods of removing it or preventing it forming hard scale. The older remedies mostly involved the use of organic matters which acted by interfering with the crystallization of the sulfate, and thus rendered the deposit pulverulent or at least friable. Much organic matter, however, in a boiler water may cause corrosion or priming, and we find a tendency at the present day to the use of direct precipitating agents, among which may be mentioned trisodium phosphate and sodium fluorid. Both these substances convert all calcium and magnesium compounds into insoluble flocculent precipitates, yielding also highly soluble and non-corrosive sodium salts. They seem to meet the practical issues very well, and are in extensive use.

In conclusion, I wish to express my thanks especially to Mr. John Overn, who furnished me with a number of samples of boiler-scale from different waters in use in this locality.

DISCUSSION.

JOHN BIRKINBINE.—Dr. Leffmann has incidentally referred to the hardness of water. I would like to know if he regards the soap test as of any value. Is it applicable as a preliminary test for boiler-water? Suppose two waters were to be compared, one of which was known to produce very little scale: now, if this required less soap than the other, would I be justified in supposing that it would produce less scale? Would it be safe to infer that the one that required the less soap would form the smaller amount of scale?

E. M. NICHOLS.—What has been your experience with the barium test to determine the scale-forming ingredients? I would like to know, also, whether you have pointed out the difference in effect between the carbonates and sulfates. For example, the water may show a marked degree of hardness by the soap test and yet deposit carbonates in the boiler, easily washed out and not becoming hard.

DR. LEFFMANN.—I regard the barium test as a very good guide to the estimation of the maximum hard scale that the water might form. In using the soap test the distinction between carbonates and sulfates is easily made by determining the hardness before and after boiling. In answer to Mr. Birkinbine's question, I will say that I think the results might be unreliable. Magnesium salts are a disturbing influence.

JAMES CHRISTIE.—I have been fortunately situated for many years in a district where the water for steam boilers is obtained from the surface drainage and the springs of the surrounding hills, the water being comparatively free from mineral matter; it is clarified by subsidence in storage dams and tanks. Consequently I have little experience in the difficulties attendant on incrustation in steam boilers. With others in our vicinity using the Schuylkill water the usual practice is to discharge the feed-water into the boiler so that deposit occurs as near the blow-off as possible, and to give a liberal discharge at the blow-off once a day. This is very effective, as the deposit is largely removed before it has time to harden. The use of petroleum as a solvent is also practised to some extent, and is considered good treatment by many. I have understood that when the feed-water is entirely drawn from surface-condensers the boilers suffer more from corrosion than if the water were less pure. This, if true, confirms a statement by Dr. Leffmann, that very pure water may not be the best to put in steam boilers.

E. K. LANDIS.—I should like to relate in this connection an experience of my own at the Pottstown Iron Co.'s plant. The blast furnace to which I was attached went out of blast, and at my suggestion the question of water-purification was taken up. We were using Schuylkill water, which was at that period of the year usually quite muddy. The amount of sulfates in it was determined and some efforts made to get rid of them, but we could not succeed in getting any apparatus for that purpose without expending more money than was considered desirable. Another experiment was tried. We supposed that by filtering out the suspended matter a gain would be made, but instead of that we found it was anything but desirable to do so, because the filtered water formed a hard sulfate scale; the mud in the unfiltered water was sufficient in quantity to prevent that scale from becoming hard. When the mud was allowed to remain, the scale was soft and easily removed. Another experience was this. Some years ago I was at Bellefonte trying to blow in a furnace. A dealer in boiler-compounds came to see me, and although I told him I was too busy then, but if he would come back in two or three weeks I would take the matter up, he still kept talking, and I asked him if he could refer to any one who had used his compound satisfactorily. He mentioned Cofrode and Saylor. He said the system his company followed was to analyze the scale, and if the first compound did not work, change the ingredients. I suggested to him that perhaps it might corrode the boilers. He said no, the company would guarantee it would not. I inquired of a friend of mine who was at the time with Cofrode and Saylor, and found that the makers of the boiler-compound had guaranteed to keep the boilers free from scale. If scale formed, they analyzed it and sent a compound that would work satisfactorily for a couple of months; then the nature of the scale-forming ingredients changed and scale again formed. The scale again was analyzed and the dope changed, but in a short time it corroded the boiler-plates and they had to put in a new set of boilers. It was then found that the guarantee was not worth more than the other guarantees of which we have heard so much lately.

GEO. B. HARTLEY.—Referring to some matters touched upon in the paper, I will say, first, that while it is true that the engineer has no control over the quality of feed-water to be used in the boiler, he too frequently ignores this question altogether. The scale-forming ingredients should be ascertained and the boiler designed accordingly, incrustation from organic causes being much more rapidly created in a boiler overcrowded by tubes or where the tubes are spaced so closely together as to impede circulation. Many instances of these spaces being blocked entirely have been found in boilers along the Schuylkill River above Norristown. This is also a loss of power and a waste of fuel. The use of caustic soda has proved beneficial, one of its objections being the liability to cut out joints and create leaks in steam-pipe connections. A comparison of the Schuylkill and Delaware River waters will show that the Delaware water contains little or no scale-forming matter at this point of the river (Philadelphia). Boilers recently inspected in Camden, after being in service over five years, show heating surface perfectly clean and free from scale. It is needless to say that it is impossible to keep boilers in this satisfactory condition when Schuylkill water is used.

B. H. COFFEY.—It has been my practice during the last few years in removing scale to let the boiler cool before running the water out. Under this condition I find the scale very soft, while if the water is blown out when hot the scale becomes very hard and difficult to remove. The action of the hot plates on the dry scale appears to change its nature to a considerable extent, but I can not explain it.

DR. LEFFMANN.—I think that is due to a change in the physical condition—that is, the crystallization of the scale. The character of the scale is determined in a measure by the manner in which it is crystallized. If allowed to form a certain kind of crystals, they probably interlace with one another and produce a firm mass. Hard scales are due largely to crystalline substances slightly soluble in water, allowing at the last moment a sort of cementing by the crystallization of the last portions between the interstices of the earlier deposits. This does not occur to the same extent with the carbonate. Speaking of some of the methods of removing scale, I may mention an invention made some years ago called the "Anti-incrustator." I presume some of the members will recall it. I have seen a number of experiments made with it.

MR. CHRISTIE.—I remember the anti-incrustator very well; it was exploited and used largely for a short period over thirty years ago. A curious circumstance connected with its use was that occasionally a customer would report an increase in the incrustation by its use. Then the agent would look wise, talk of "reversed polarity," etc., and use the incident as a convincing argument of the efficacy of the instrument in affecting the deposition of mineral solutions.

DR. LEFFMANN.—There is certainly some influence by electric currents determining the direction in which sediment might flow. It is said that smoke and fogs may be influenced by electric currents. When more is known of the relations of electrochemistry we may get more light.

Mr. Nichols.—Mention has been made of the effect on the scale or deposit by allowing the boiler to cool off before blowing down. There seems to be some good chemical reason for any such result. Is it not likely to occur more from a carbonate being formed, which would dry and harden under the effect of extreme heat? or may it be by the influence of other foreign matter deposited with the sulfate that the slow cooling off would make a soft scale or slush, while with the hot plates on the boilers might ordinarily make hard scale? I have had charge of boilers which, by allowing them to cool off very slowly and keeping them full of cold water, and allowing the brick-work to cool down, I could clean them very quickly; while if I allowed the boiler to blow off twenty-four hours afterward it would form a hard, dry scale.

Dr. Leffmann.—I can not answer that question except by suggestions. I do think that crystallization has something to do with it. Calcium carbonate, for instance, exists in several crystalline forms. One of these forms masses which are readily cleavable and brittle; other forms are tougher. The different forms are produced under different conditions. When a substance—*e. g.*, calcium sulfate—is deposited only at a high temperature, some of it may redissolve as the water cools, and thus a slightly solvent action be exerted upon the scale. Some of the differences, therefore, between scale may be physical rather than chemic. At the point at which the iron is hottest the magnesium compounds are partly converted into magnesium hydroxid, and this, of course, changes the physical nature of the scale.

The Chairman.—One question offered for discussion is the comparison between the effects of Delaware and Schuylkill water. Mr. Twining can doubtless give us some information on this point.

William S. Twining.—Delaware water forms very much less scale than Schuylkill. We have been using trisodium phosphate during the past two years, and very little scale has been formed.

W. C. Furber.—I believe the boiler inspectors forbid the use of artesian-well water in boilers.

Mr. Hartley.—That is not correct. Artesian-well water is being used at the mills at Ninth and Tasker Streets, Philadelphia, in nine boilers. It is an excellent water for boiler use.

Mr. Furber.—At one of the large office-buildings in this city an artesian well was drilled for the purpose of saving water-rent, and I believe the boiler inspectors refused permission to use the water and it was abandoned.

Mr. Hartley.—Perhaps the water was found to be unfit for boiler purposes. How they could prohibit the water before it was found to be unfit, I do not know.

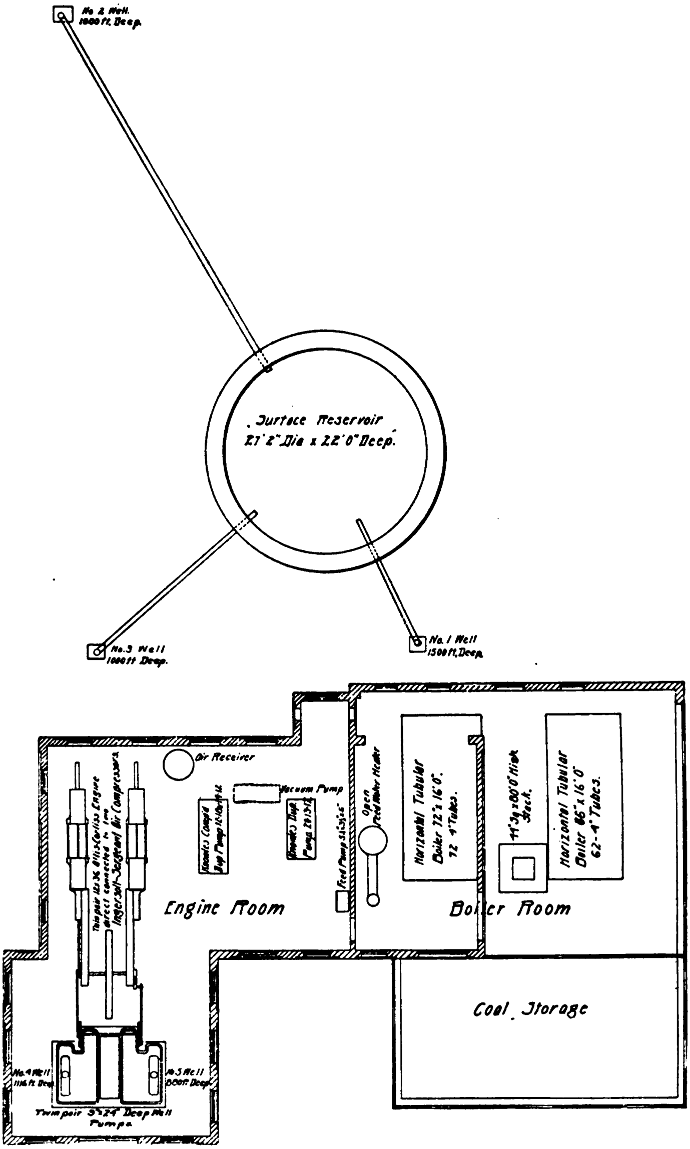
A DEEP-WELL PUMPING PLANT AT WAUKESHA, WIS.

J. W. LEDOUX.

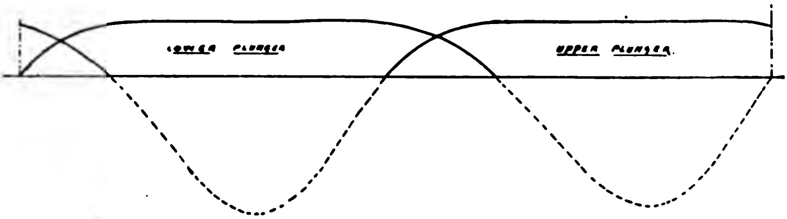
Read April 16, 1898.

In February, 1897, the writer was sent to Waukesha, Wis., by The American Pipe Manufacturing Co. to examine the water-works plant for the purpose of determining its purchase value, and in June, 1897, the works were acquired and reorganized under the name of the "Waukesha Water Works." A complete test of the pumping plant then made showed that a maximum of 1,000,000 gallons was being consumed per twenty-four hours, and an average of 723,000 gallons, or 1395 gallons per tap. The water came from three artesian wells, located as shown in annexed sketch, two of the wells being 1000 feet deep each and the third 1500 feet deep, all having 6-inch drop-pipes to a depth of 300 feet. The remaining portions of the wells were somewhat over 6 inches in diameter, and with the exception of about 20 feet were in solid rock for their total depths. The formation is known as St. Peter's sandstone for about 600 to 1000 feet, and Potsdam sandstone below that.

At about the center of the space occupied by these wells was a cylindric brick-lined reservoir 25 feet deep and about 27 feet clear diameter. This reservoir proved to be water tight, and afforded a ready means of measuring the capacity of the artesian wells and of calibrating the pumps. The pumping station is located 30 or more feet to the north of the reservoir, and contained: a twin pair of 12 × 36 Corliss engines, having the piston-rods extended back to two 14½-inch Ingersoll air-compressor cylinders; a Knowles compound duplex pump, 12 × 18½ × 14 × 12; a surface condenser in the discharge pipe and small direct-acting air pump; a Knowles simple duplex pump, 20 × 13 × 12. There were two horizontal return tubular boilers, each nominally rated at about 110 horse-power, based on 12 square feet of heating surface per horse-power. The stack was of brick, 80 feet high. The boilers were fed by a duplex feed-pump, taking the water from an open heater into which exhausted the air-


No. 2 Well
1000 ft. Deep.
Surface Reservoir
27'2" Dia x 22'0" Deep.
No. 3 Well
1000 ft Deep.
No. 1 Well
1500 ft. Deep.
Air Receiver
Vacuum Pump
Knowles Compd Dup Pump 12x10x12
Knowles Dup Pump 28x13x12
Feed Pump 5½x3½x5"
Open Feed Water Heater
Twin pair 12x36 Allis Corliss Engine direct connected to two Ingersoll-Sergeant Air Compressors
Engine Room
Horizontal Tubular Boiler 72"x 16'0". 72 4" Tubes.
4'3 sq x 80'0" High Stack.
Horizontal Tubular Boiler 66"x 16'0" 62-4" Tubes.
Boiler Room
Coal Storage
No. 4 Well 1116 ft. Deep
No. 5 Well 800 ft. Deep
Twin pair 9"x24" Deep Well Pumps.

General Plan of Deep-Well Pumping Plant of Waukesha Water Works, Waukesha, Wis.



THEORETIC DISCHARGE-LINE OF CONTINUOUS-FLOW DEEP-WELL PUMP.

DISCHARGE-LINE.

Pump No. 5 **Running.**
Rev., 28.9.

Head above Gage, 144.0 ft.
Lift below " 61.0 "
Total Gage, 205.0 ft.

ATMOSPHERE-LINE.

DISCHARGE-LINE.

Pumps Nos. 4 **and 5 Running.**
Rev., 24.7.

Head above Gage, 144.0 ft.
Lift below " 73.0 "
Total Gage, 217.0 ft.

ATMOSPHERE-LINE.

ACTUAL DISCHARGE-LINE OF CONTINUOUS-FLOW DEEP-WELL PUMPS, TAKEN FROM MAIN DISCHARGE TEE OF NO. 5 WELL, MARCH 17, 1898.

The lines as **printed above are sensibly straight; in the original they show slight variations from the horizontal.**

pump, engine, and feed-pump. Close to the air-compressor was located a vertical air-receiver, from which 2½-inch air-pipes were run to each well, and 2 inch air-pipes into the wells approximately 224 feet. The ends of the pipe were reduced to ¾ of an inch, with a short return as in the usual air-lift construction. The air-pipe entered the 6-inch drop-pipe through a cap in the top, below which was the horizontal discharge tee and pipe running to the reservoir. When the engine was first started, the air-pressure in the receiver usually went up to about 100 pounds, and as soon as water was flowing the pressure dropped back to 60 pounds. For several days tests were made to determine the capacity of the wells, the final result of which was 750 gallons per minute while drawing them down to respective depths of 89, 98, and 106 feet, or an average of 97.7 feet. It may be interesting here to state the method by which the lift of wells was determined. There was no means of dropping a float down the space outside of the drop-pipe, as these spaces had been filled to a considerable depth with seed-bags and cement. Screw-connections were therefore made in the caps alongside of air-pipes, and 270 feet of pipe, composed of 1¼ inches for 120 feet and ¾ of an inch for the lower 150 feet, were hung from the caps. The depth to water was then easily determined by means of a light float let down into the 1¼-inch pipe and suspended by a silk thread.

The following is the result of a test made on June 29, 1897:

Boiler Trial.

Duration of trial, ...	8 hours
During four hours of this time the air-compressor and pumps were run together; for two hours the pump was run alone, and for one and one-half hours the engine was run alone.	
Kind of coal used, ...	Westville, Ill., "Run of Mines."
Steam pressure: pounds above atmosphere, ...	90
Temperature of feed-water, ...	187° F.
Evaporation per pound of coal, ...	6.86
" " " " from and at 212, . . .	7.30
" " " combustible from and at 212,	8.38
Boiler H. P. developed, ...	123.1

Pump and Air-Compressor Trial.

Compressor, H. P. indicated, ...	108.7
Pump, H. P., ...	38.0
Total indicated H. P., ...	146.7
Steam consumption in pounds per I. H. P. per hour, .	32.34
Pounds of coal per I. H. P. per hour, ...	4.5
Rate of pumping gallons per minute, ...	722

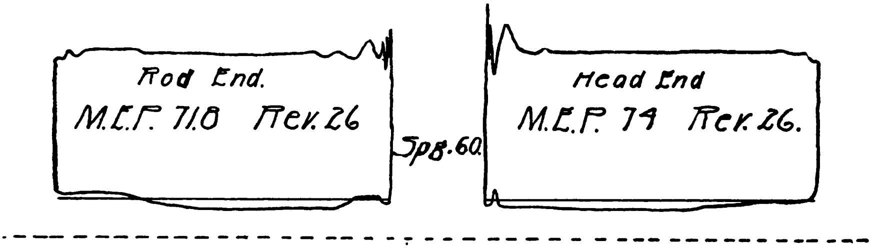
Trial of Pump alone.

Gallons per minute,	672
Total head in feet,	165
Indicated H. P.,	36.7
Actual water H. P.,	28.4
Steam per indicated H. P. per hour, pounds,	60.25
" " actual " " "	81.6
Coal per indicated H. P. per hour,	8.56
" " actual " "	11.15
Duty in foot-pounds per 1000 pounds of steam,	24,250,000
" " " " 100 " " coal,	17,750,000

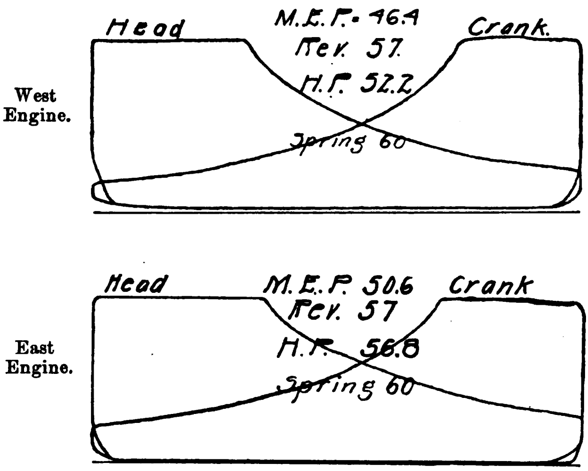
Compressor Trial (Air Lift).

Steam pressure, pounds,	92.5
Air " "	65
Gallons per minute,	780
Average lift, feet,	97.7
Indicated H. P., steam,	108.7
Actual H. P., water,	19.3
Steam per indicated H. P., hour, pounds,	29.45
" " actual " " "	165.9
Coal " " " " "	24.1
Duty in foot-pounds per 1000 pounds of steam,	11,940,000
" " " " 100 " " coal,	8,220,000
Efficiency of air-lift, per cent.,	17.75

Several later tests of eight hours' duration, made carefully by J. E. Gibson, M. E., confirmed these results and showed that the air-lift efficiency ranged between 16 and 18 per cent. Several expedients were then tried for the purpose of increasing this efficiency, none of which proved of decided benefit, and as the efficiency of the air-compressor was high, the above results may be taken as representing fair practice. Up to this time the average coal consumption had been about 12,000 pounds every twenty-four hours. To reduce the expenses of the station the writer had originally recommended sinking a shaft between the three wells; from thence driving drifts connecting wells with shaft and placing the water end of high-duty pumps at the bottom of shaft. The steam end of pumps would of necessity have been located at the surface of ground, for the water level varies from 10 to 30 feet below surface when pumps are idle. Having high-grade Corliss engines from which the air-compressor could easily be detached, the preferable plan was to transmit the power to crank-wheels located over shaft by means of a rope drive, and, of course, do all the pumping with one operation. After careful consideration and conferring with manufacturers of deep-well machinery, it was finally decided to sink two artesian wells, located 10 feet apart, as shown in the sketch, and install two deep-well pumps manufactured under patents of E. E. Johnson, M. E., of Chicago. The reason for this decision was that the guaranteed efficiency of the pumps was unusually high, and by having the extra wells, an almost complete duplication of the whole plant was secured. Although advised against them by prominent engine builders, we adopted side rods as the means



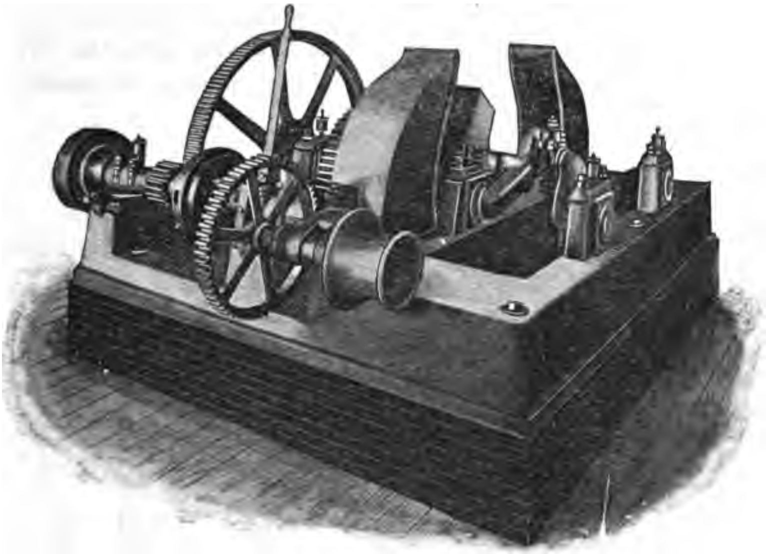
Cards Taken From Water End, Knowles Compound Condensing Duplex Pump, 12″—18½″—14″—12″, June 29, 1897.



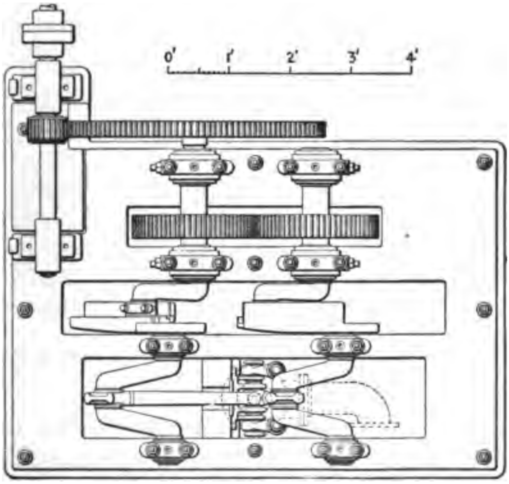
Cards From Twin Pair, 12 x 36 Inches—60 Rev. Allis-Corliss Engines, Tandem Connected to Twin Pair, 14¼ x 36 Inches. Ingersoll-Sergeant Air-Compressors. Total H. P., 109.0. (Waukesha Water Works.)

of transmitting power from the engine shaft to pinion shaft of pumps. The near-by location of wells made necessary by the boundary of property then in litigation made belting impracticable, and gears would require radical alteration of the engine and have other practical disadvantages. The pumps were designed for 350 gallons per minute each under a total lift of 260 feet and a piston speed of 120 feet per minute, the guaranteed efficiency being 70 per cent. measured by the ratio of foot-pounds of water lifted to the foot-pounds of work delivered to the pinion shaft. The first well was sunk 1116 feet, the second 860 feet, and a test of eighteen hours' duration with the air-lift showed their capacity to be at least 750 gallons per minute, with a lift of 100 feet.

The new pumping-plant consisted of two double-acting deep-well pumps, each provided with the Whitworth "quick return" device. The plunger-valves are of the stepped-cone type, in 9-inch working barrels, about 100 feet below floor level, but arranged to pump the water to a depth of 120 feet by means of a length of suction pipe. The pumps are operated by gearing from a pinion shaft provided with two friction clutches, placed so that either or both pumps can be run at will. The proportion of gears is 54 to 142. On each end of the pinion shaft is a disc having a crank-pin set at an angle of 90 degrees from the other. The cranks are made to revolve by means of side rods, 8 feet 7½ inches long, connected with the corresponding cranks of the Allis twin Corliss engine, provision being made whereby either engine could operate the two pumps while the other runs the air-lift or remains idle. The side rods gave entire satisfaction in their running. A complete test of the new pumping plant was made on March 7, 1898. The total water-lift ranged through the test from 240 to 261 feet. The depth to water in well was measured by means of air pressure furnished by a small compressor attached to eccentric on pump shaft. A separate half-inch air-pipe was connected with the small receiver of the compressor and run down into each well to a depth of 120 feet. A gage reading to feet was attached to the receiver. The best way to operate this device was found to be by shutting off air-pipes below the receiver and pumping into it an excess of air-pressure. The valve between the receiver and compressor was then shut and the compressor relief-valve opened. Then the air was turned gradually into the well and the gage index slowly revolved

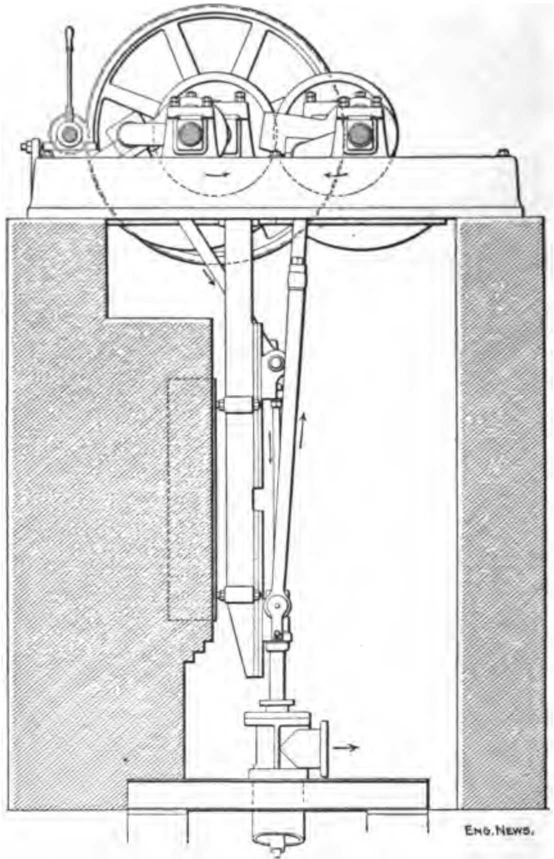


General View of a Continuous-flow Deep-well Pump.
(*Designed by E. E. Johnson, M. E.*)

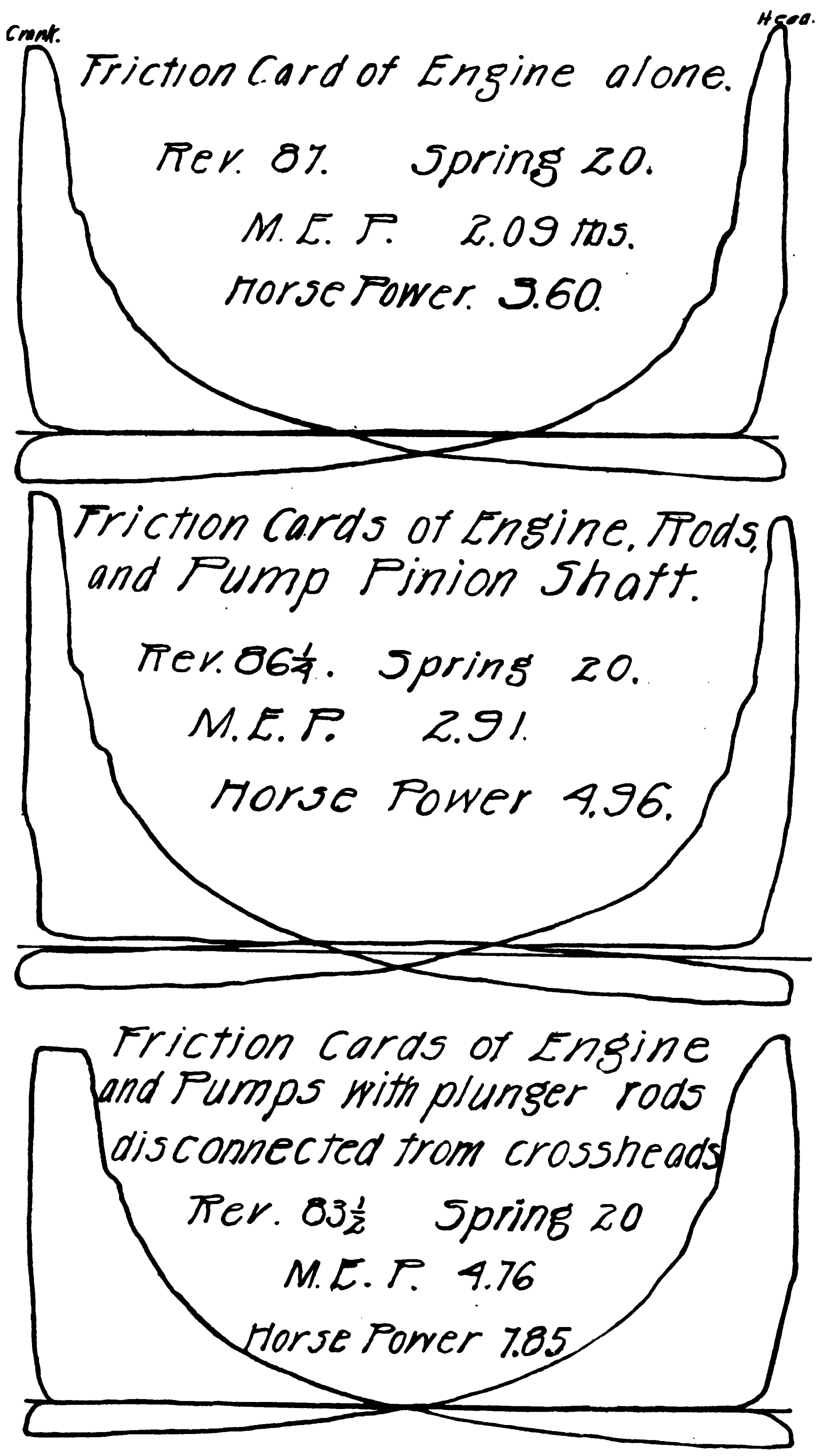


Plan of Continuous-flow Deep-well Pump.

toward the zero point, until when it came to rest the reading of gage indicated almost the exact height of water column above the bottom of the air-pipe. Subtracting this height from 120 gave the lift in feet below floor level. The test for slip of pumps was made by pumping into the reservoir through a 10-inch valve, throttled so as to cause nearly the same head as ordinarily produced by the standpipe pressure, and measurements were taken every ten minutes. As the separate measurements agreed closely with the average of all, this



Sectional Elevation of Continuous-flow Deep-well Pump.



FRICTION CARDS FROM EAST ENGINE OF TWIN PAIR OF 12 x 36 INCH ALLIS-CORLISS ENGINES, MARCH 6, 1898.

may be relied upon as correct. All the other observations were taken every half hour, and the following results are the average of all:

Date of test, March 7, 1898, commencing 3.50 P. M., ending 11.50 P. M.

Duration of test, ...	8 hours	

Test for Displacement shows:

One revolution of engine pumps, ...	8.888	gallons
" " " two pumps, ...	23.317	"
Estimated displacement, ...	23.16	
Total revolutions of engine, ...	37,729	
" gallons pumped, ...	335,335	
" feed-water consumed, ...	13,620	pounds
" coal used, ...	2,111	"
" ashes, ...	145	"
Per cent. of ash (wet coal), ...	6.85	
Boiler pressure, ...	93	pounds
Vacuum, ...	24	inches
Temperature of feed-water, ...	195° F.	
Boiler H. P., ...	52.3	
Rated Boiler H. P., ...	125	

Average Working Pressure on Pumps.

Lift below gage, ...	96.0	
" above "	154.6	feet
Total lift, ...	250.6	feet
Revolutions per minute of engine, ...	78.6	
" " " " pumps, ...	29.9	
Feed-water consumed per hour, ...	1702.5	pounds
Coal burned per hour, ...	263.875	"
Friction load of engine alone, ...	3.66	H. P.
Friction load of engine, side rods, and pinion shaft,	5.04	H. P.
Friction load of engine and two pumps, with plunger rods disconnected, ...	7.88	H. P.

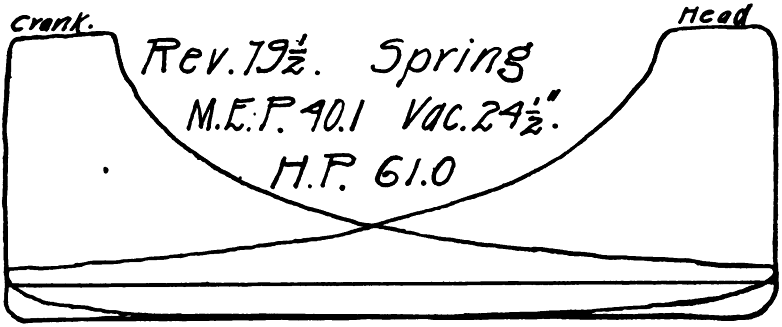
PRINCIPAL RESULTS.

	Col. 1.	*Col. 2.*
Evaporation per pound of coal, . .	6.44	6.86
Evaporation per pound of coal from and at 212, ...	6.84	7.30
Indicated H. P., ...	61.3	146.7
Actual H. P., ...	45.9	48.7
Steam per indicated H. P., hour, . .	27.8 pounds	32.34
" " actual H. P., hour, . . .	37.15 "	97.4
Coal " indicated H. P., hour, . .	4.3 "	4.5
" " actual H. P., hour, . . .	5.75	13.55
Duty per 100 pounds of coal, .	34,500,000	14,600,000
" " 1000 " " steam,	53,300,000	20,350,000

FINAL RESULTS.

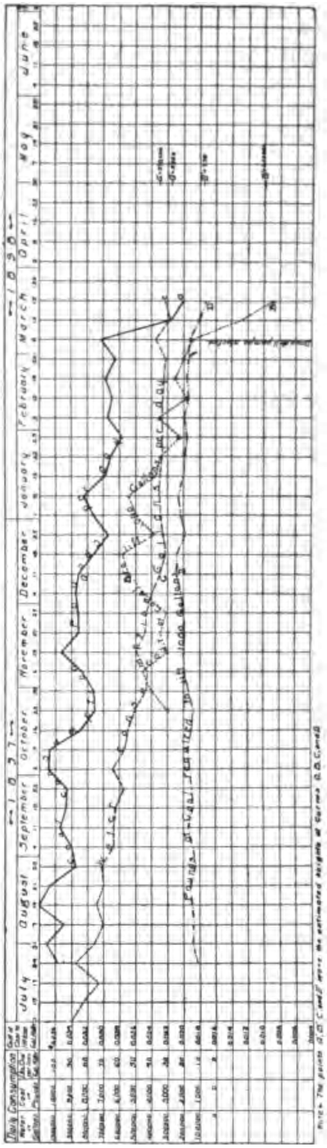
	Guarantee.	*Obtained.*
Gallons per minute, ...	700	699
Efficiency of pumps, as per contract, ...	70 per cent.	80.1 per cent.
Total lift, ...	260 feet	250.6
Efficiency based on indicated H. P. of engine, ...		74.8 per cent.

The pumps would have discharged above their rated capacity and did during half the run, but the attempt was made to have them work at the capacity guaranteed.



AVERAGE-LOAD CARD FROM EAST ENGINE OF TWIN PAIR OF 12 x 36 INCH ALLIS-CORLISS ENGINES DRIVING TWO CONTINUOUS-FLOW DEEP-WELL PUMPS, MARCH 7, 1893.

In column 2 are given the corresponding results as previously obtained while pumping to standpipe with the old method, and it will be noted that if the evaporation had been as good as in the previous test, the duty per 100 pounds of coal would have been 36,700,000 foot-pounds instead of 34,500,000. An examination of the diagram of the weekly pumping reports will show the effect of the change, for, after all, the true measure of value of the improvement is represented by the comparative annual cost of pumping a given quantity of water to the city. The question of cost of the improvements has not been touched upon, although aside from the reduction of operating expenses the expenditure would almost have been warranted on account of the advantage of duplication.



DIAGRAMS PLOTTED FROM WEEKLY PUMPING REPORTS, WAUKESHA, WIS.

DISCUSSION.

James Christie.—How was the connection made at the discharge point of the compressed air, so as to act upon the lift?

Mr. Ledoux.—The pipe was simply run down into the well about 225 feet and reduced at the bottom to ¾ of an inch and turned up for 2 or 3 inches. The idea is to get the air down to a sufficient depth so that the mixture of air and water will form a low specific gravity. We thought that by having a more thorough admixture and reducing the air to a spray by means of a perforated nozzle we could get a better result; but found no material difference. The pipe might as well be left open at the bottom.

Max Livingston.—Is not this the system known as the Pohlé air-lift? Its successful operation depends on a supply of water sufficient to maintain about 60 per cent. submersion. When these conditions prevail the Pohlé air-lift has been found to work more advantageously than pumps, but the wells that have come under my notice were not nearly so deep—only from 50 to 150 feet—as those referred to in the paper.

Mr. Ledoux.—An ordinary method of pumping artesian wells is by direct-acting steam-pumps. I believe that with such an inefficient pump in point of economy an air-lift might compare favorably, but I never heard of any case in which the efficiency has gone over 24 per cent. You will note that we got about 18 per cent. We spent two or three weeks trying to increase the efficiency by varying the amount of submergence, and found 50 to 60 per cent. to give best results. We also tried to do away with throttling the respective air-pipes by lowering the pipes in two wells to a depth so that all the air-pipes might remain open; but there was not much, if any, advantage in doing away with surface throttling. I am of the firm opinion that the scheme is not good for more than 25 per cent. efficiency, and I would not estimate on over 17 per cent. in practice.

Mr. Christie.—The low efficiency of the air-lift, as shown by Mr. Ledoux, is in accord with results obtained elsewhere, and is probably all we could expect from the system. Still the method is a very useful one under certain conditions, especially if the volume of water to be lifted is not large and the air can be taken from sources where it is compressed for other purposes. I have used the system for several years for lifting and distributing drinking-water at workshops, and the water is improved by the aëration and I think somewhat reduced in temperature. I do not understand why Mr. Ledoux got such low efficiency from his steam boilers. It is about 15 per cent. less than is ordinarily obtained from boilers of the same dimensions working under ordinary conditions.

Mr. Ledoux.—I would say the low results are principally due to the grade of coal we used. I think analyses of the coal would show where the trouble was. The boilers were fairly well constructed horizontal return tubular. In our latest the grate area was too large, but in the first test we were running the boilers up to their capacity, and hence at a rate for which they should give the maximum economy.

E. M. Nichols.—I am inclined to think the inefficiency of the boilers is due to the quality of the coal. I have had considerable experience with that class of coal in the State of Illinois, and when we got 7 pounds evaporation duty per pound of coal we thought we were doing pretty well, and it is the general rate of evaporation with that fuel and horizontal return flue boilers, as ordinarily set. In regard to the efficiency of the pumps, I have never personally had anything to do with the air-lift, although I operated the water works 50 miles west of Waukesha, at Madison, Wis. The water-supply for a majority of the towns in that section of the country is derived from artesian wells, similar to those at Waukesha, even as far south as Rockford and Elgin, Ill. I know that they have in some of these cities installed the Pohlé air-lift, so that they could get more water out of their wells than by the ordinary type of deep-well pump, and it was demonstrated that their efficiency was very low, in no case exceeding 20 per cent. So far as the condition of the water is concerned, as regards sand and foreign matter, which is likely to cut out the valves, I would say that I do not think it has ever come in as a factor in that region, as the water is remarkably pure and clean. I think that a majority of the water works which installed the Pohlé air-lift have abandoned them as either impracticable or too expensive to maintain, and there is no doubt, as Mr. Ledoux has shown us this evening, that the long plunger-rod and barrel of the pump, low down in the well, give much greater efficiency.

Mr. Ledoux.—There is a very elaborate paper with full discussion on this subject in the "Proceedings of the Western Society of Engineers" for March 3, 1897. The paper is by E. E. Johnson, M. E., patentee of the pump. At Indianapolis they have a large air-lift system and pump a large quantity of water, but I believe the lift is very low indeed. The air-pipes are not down more than 50 or 60 feet and the lift is probably no more than 8 or 10 feet, so there is not much difficulty in pumping the water there. The water contains a great deal of iron. They thought by means of the air they could bring the iron in solution to an insoluble form by the increase of oxygen. The plan, although beneficial, was not entirely effective.

Mr. Christie.—Did you try heating the air?

Mr. Ledoux.—No.

Mr. Christie.—You would probably have found it an advantage to do so.

Mr. Ledoux.—We thought that the water would cool it so that reheating, as it could not be done at the nozzle, would not have much effect.

W. P. Dallett.—I wish to call attention to a paper written by Prof. Marsden, referring to the same apparatus. This paper bears out the statement made by Mr. Ledoux. It was published in the "Engineering Record" of April 2, 1898.

Mr. Christie.—What is that quick return of which you speak?

Mr. Ledoux.—I expected to have a lantern slide to illustrate that, but it did not come. I can not describe it adequately.

John Birkinbine.—If I understand Mr. Ledoux correctly, he has placed before us three propositions: First, with the air-lift pump he obtained a duty of about 8 million foot-pounds for 100 pounds of coal; second, with a compound condensing duplex pump he obtained a duty of 24½ million foot-pounds; and, third, with a reciprocating engine, driving deep-well pumps, he obtained 34½ million foot-pound duty. I also understand that these duties were obtained under practically similar conditions as to fuel used, surroundings, etc., and that the delivery of water was actually measured. That suggests the comparison of published duty and the duty actually obtained. I have in mind a specification which provides for duty based upon the evaporation of 10 pounds of water, delivered as dry steam at 150 pounds pressure at the pumping engine, from the temperature of the injector water, which is ordinarily 40° to 70°. I have been looking for a boiler to do that work. With tests such as reported by Mr. Ledoux we are enabled to judge frankly what the machinery was doing day in and day out. Perhaps Mr. Ledoux could have carried on the tests to show higher duties, but I understand these given represent every-day work, without using selected coal, but taking the coal ordinarily supplied and doing the work under normal conditions for which the pumps were operated. Those are the kind of tests from which to judge of the actual efficiency of machinery. I do not mean to suggest that empirical tests are not reliable, and we have no way for comparing pumps working under different conditions and with different fuels except by starting with some standard. However, the practical test is what the engineer wants more than anything else. We want in our tests to know not only the fuel consumption but also the running expenses of pumping machinery. A set of pumps may show economy of fuel, but when the attendance and repair bills are added the sum may show greater expenses at the end of the year than with other machinery indicating poorer fuel economy.

MR. FALKENAU.—Is the pump of the oil-well variety, with a ball valve?

MR. LEDOUX.—No; it has cone valves. There are two plungers 9 inches in diameter having conical valves, and the rod attached to the lower plunger works within the upper plunger. It is a double-acting pump—one plunger goes down while the other comes up; but the down-stroke is very fast and the up-stroke slow, so that each plunger begins to raise the column of water before the other finishes the up-stroke, and that is caused by this mechanical feature which is called the "quick return."

MR. FALKENAU.—How long has the pump been in use?

MR. LEDOUX.—This make of pump has been in use for about a year and a half.

MR. FALKENAU.—Is this a record extending over that period?

MR. LEDOUX.—No. The first pump was put in about a year and a half ago. There are probably four or five in use now.

MR. FALKENAU.—My experience with the old-fashioned oil-well pumps was that the ball-valves would soon become defective and the efficiency of the pump suffer by slip. I think that would apply to quite an extent to any form of deep-well pump, and whether that would not, in the long run, vitiate the apparent efficiency as compared with the Pohlé air-lift is a question worth considering.

Mr. Ledoux.—We have had experience with different kinds of valves and plungers; for instance, with the Downie pump, at Tallahassee, Florida, which has been in use about six years, new cup-leathers are required about twice a year. At Bryn Mawr we have a single-acting deep-well pumping engine and a lift of about 310 feet. We first had some trouble with the plungers, but only once with the ball-valve, and that was soon remedied. We have to take out the plungers about once every three months and put in new cup-leathers. Mr. Johnson is now experimenting on a device that may overcome the trouble due to cup-leathers, which sometimes turn and cause damage to the engine or other parts of the machinery. He has now a water-packed plunger consisting of alternate circular discs of brass and leather, forming a water packing. Probably there would be more slip with that kind of plunger, but it would be safer and increase the ultimate efficiency. This form of plungers has not been in use long enough to determine their effectiveness.

John C. Trautwine, Jr.—When visiting the water works at Asbury Park about a year ago, I found in use a modification of the Pohlé air-lift pump, in which, if I remember rightly, a vertical upward discharge had been substituted for the usual horizontal discharge impinging directly against the walls of the well. The modification was the invention of a resident of this city. The superintendent informed me that very much better results were obtained after the adoption of the modified form of discharge, and, in view of the low efficiency of the air-lift, as found by Mr. Ledoux, I would ask whether, in his investigations, he made use of this form of discharge.

Mr. Ledoux.—I am somewhat familiar with the methods recommended by that gentleman. I tried some of his devices at Waukesha, and while I can not positively say they are not all he represents, I am under the impression his claims are not well founded. Theoretically, the water should have a free discharge directly over the drop-pipe, so that air-pockets are not formed, which would restrict the flow of water and cause a back pressure. However, we did not find much loss due to the horizontal pipes at the surface of wells. Another claim is that by having at the bottom of air-pipe a capped connection, perforated with small conical-shaped holes converging outward, the air and water could be most thoroughly mixed with the least resistance. We thought it would be an advantage, and tried it to see if we could get increased efficiency. We had the pipe shaped conical and bored the holes from the inside as just stated, but we did not find any increased efficiency, and would probably have got just as good results if we had left an open pipe in the bottom of the well.

Mr. Trautwine.—I forget what the particular improvement was, but I understood that their operation was much more satisfactory.

Mr. Ledoux.—At Asbury Park a remarkable difference was claimed—namely, that 118 gallons were raised per pound of coal while formerly 68 gallons were raised.

Mr. Trautwine.—At Asbury Park the artesian-well water is heavily charged with iron in the form of a soluble ferrous salt, so that in its natural state the water is quite transparent; but the aëration coincident with the use of the air-lift further oxidizes the iron and brings it into the state of the insoluble ferric oxid, which renders the water turbid. Without subsequent treatment this would, of course, be a very decided objection ; but in view of the subsequent filtration this conversion is not only an advantage, but is absolutely essential to the removal of the iron, for the dissolved ferrous salt would, of course, pass through the filters unaffected, whereas the ferric oxid held in suspension is retained upon them.

THE PRESIDENT.—What was the ratio between water-volume and air-volume in that portion of the pipe under the operation?

MR. LEDOUX.—It took about 7 cubic feet of air, at atmospheric pressure, to raise 1 cubic foot of water under 100-foot head. The efficiency of the air-compressor was 86.7 per cent. Thé air-pressure, of course, had to be at least equal to the water-pressure at the air-nozzle. In starting, the air-pressure was greater than it was after water began to flow.

THE PRESIDENT.—As I understand the matter, as that bubble of air rises near the top of the pipe there is a column of water less and less in height, and the bubbles are longer at the top of the pipe than at the bottom. Then the volume of 7 to 1 would be the volume of air at middle of pipe.

MR. LEDOUX.—No, not until air had again expanded to atmospheric pressure.

MR. BIRKINBINE.—Mr. Ledoux says he measured an amount of water. Can he give us the amount of slip when it was possible to measure it? Were the tests of the three pumps made so as to be equitable as to coal and other conditions?

MR. LEDOUX.—The slip of this Johnson pump was practically nothing. It is not easy to calculate the displacement of this pump per revolution. Part of the time both plungers are moving in the same, and part of the time in opposite directions ; hence the theoretic discharge can only be determined by means of a diagram. According to Mr. Johnson's diagram the slip was negative, and more water was pumped than was indicated. He has found that to be the case in several instances, and I believe it is quite possible that this is usually the case for this class of pump. The slip in the duplex pump was very high—running slow, as much as 10 per cent.; and the minimum was about 7 per cent. This was an inside plunger-pump, water-packed. The duty of the air-lift was determined for ordinary actual conditions. The duty of the duplex pump was not so high as it should be. I think the pump was working under a disadvantage. A pump of that kind should give a duty of about 40 million foot-pounds per 1000 pounds of steam.

MR. BIRKINBINE.—It is not what the pump should do, but whether the conditions under which that brief comparison I made of 8, 24½, and 34½ millions had been fairly equitable ; that is, whether the conditions had been equal for each case, the coal being practically the same as well as the other data.

MR. LEDOUX.—Yes. The results were obtained under practically the same conditions in every case.

MR. TRAUTWINE.—The Bureau of Water in this city is frequently charged with making exaggerated statements as to the quantity of water pumped. Our estimates are, of course, and necessarily, based upon plunger displacement, but from the amount indicated by the number of strokes we make a deduction to cover losses by slip and otherwise. In the case of the Worthington pumps, we deduct, on this account, 5 per cent., and a less percentage for fly-wheel engines, which, by their construction, are compelled to make their full stroke. In order to ascertain how near the truth these estimates come, we recently made a test of the new vertical, triple-expansion, single-acting, fly-wheel pumping engines built by the Southwark Foundry & Machine Co., of this city, at our Queen-Lane pumping station, pumping into the north basin of Queen-Lane reservoir, which was used as a measuring box. We had previously ascertained quite closely the necessary corrections for leakage, vibration, etc. A test of twenty-four hours' duration gave a delivery 4½ per cent. less than that indicated by the plunger displacement, or a shortage 1½ per cent. in excess of the usual allowance of 3 per cent. We are now preparing to test, by means of Venturi meters, the discharge of the Worthington pumps at our Belmont or West Philadelphia pumping station.

Mr. Ledoux.—I have had occasion lately to test a 250 horse-power outside-packed pump, working under a head, of 260 pounds per square inch, and the slip there was 1½ per cent.

Mr. Christie.—Can Mr. Ledoux tell us if it was demonstrated that there was any negative slip or can any pump ever discharge more than its exact displacement? I recall a case many years ago in which this so-called negative slip seemed to be proved; but as it is claimed by the skeptical to be an illusion, it is interesting to know, when it appears to occur, how accurate the data are on which the estimate is based.

Mr. Dallett.—I think I have a case which proves negative slip. Some nine or ten years ago I sold a deep-well pump to a machinery dealer here, and the parties evidently did not understand the construction of it and screwed the two valves together. That pump was put in, and after four years it was sent to me for repairs, and the two valves were still screwed together. If there had not been a negative slip there, no water would have been pumped.

L. Y. Schermerhorn.—Referring to negative slip in pumps, I think that its possibility was demonstrated analytically before its existence as a fact had been well determined by observation. I once met with a commonplace illustration of the principle involved which may not be without interest. For the purpose of pumping out drill-holes in rock or submarine work, a hand-pump was arranged consisting of a piece of wrought-iron pipe about 3 inches in diameter and long enough to extend from above the surface of the water to the bottom of the drill-hole. The pumping device consisted of a light iron rod, moved up and down within the pipe by hand, upon the lower end of which was attached a conical-shaped leather valve with its smaller end downward. It was naturally inferred that a check-valve was required at the lower end of the pipe to make the pump operative. This check-valve gave no end of trouble on account of its becoming choked with small stones, which required the very frequent removal of the pump to clear out the obstructions. All at once this difficulty ceased, and the operation of the pump became surprisingly efficient. Subsequent examination showed that the check-valve was gone, and that the increased efficiency of the pump was due to its absence. By a sufficiently rapid movement of the pump-rod a continuous stream of water was discharged from the top of the pipe, in place of the intermittent stream which had formerly been discharged when the pump was provided with a bottom check-valve. The reason for this change at once became manifest. When the rod and attached conical leather valve was rapidly moved upward an ascending column of water was drawn up with it; this mass of water had sufficient momentum to carry it upward and past the suddenly reversed downward movement of the valve on the end of the iron rod, until the stream was again reinforced by the next upward movement of the valve. By this means a volume of water was discharged from the open end of the pipe considerably in excess of the volume displaced by the valve in its successive upward strokes. I believe that this principle of arranging the pump-valves so as to permit the passage of water through them during the retrograde movement of the valve has been patented and utilized in late years.

MR. CHRISTIE.—Then the moral is to leave out the foot-valve.

MR. DALLETT.—Yes; if you put a good man at the other end. There is no foot-valve in the general sense of the stationary foot-valve, and I think that is where Mr. Ledoux and Mr. Johnson got the negative slip in every case—through an action similar to that which Mr. Schermerhorn describes.

MR. NICHOLS.—Is not valve-motion the same as that in the Downie, which is practically a double-acting pump in a single barrel?

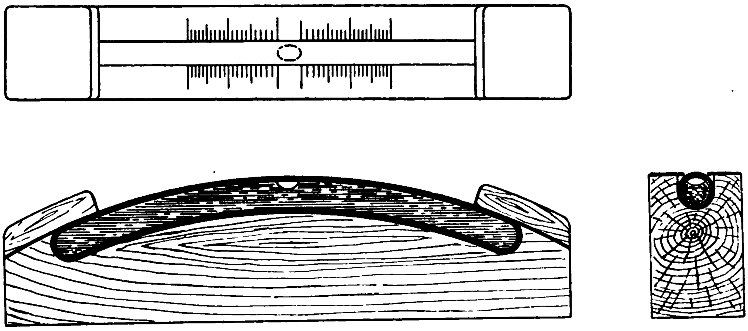
MR. LEDOUX.—It is the same with the exception of the quick return and the fact that in the Downie pump the water column comes to rest at the end of each single stroke. The two plungers move always in the opposite direction. In the Johnson pump the water never comes to rest. The maximum variation of pressure noted by gage on discharge pipe was less than 5 pounds. With the Downie crank-pump, 2-foot stroke and 30 revolutions per minute, the acceleration for each stroke would be at least 7½ feet per second; hence, without an air-chamber the pressure per square inch would be increased over 50 pounds for a mile of discharge pipe.

A NEW INERTIA INDICATOR.

WILFRED LEWIS.

Read April 16, 1898.

About a year ago I was called upon to investigate the strength of a runway intended to carry a modern traveling crane. There was no question about the ability of the columns and girders to support the maximum load in any position, but grave doubts were entertained as to whether sufficient lateral strength had been provided to resist the inertia of the crane in starting and stopping. It can readily be understood that a mass of 50 or 100 tons moving on a runway 40 or 50 feet high must, under the influence of powerful motors, have a dangerous tendency to overthrow the structure; but just what this horizontal force actually amounted to had never been determined. In my practice I had commonly assumed it to be about 10 per cent. of the moving weight, and this assumption was based upon the proportion of load carried on drivers and the probable traction of those drivers. As traveling cranes, when properly handled, do not often slip their drivers and throw the bridges out of square, I concluded that the force exerted was generally less than the friction of wheels on rails. In locomotive service this friction is known to be about 25



Lewis Inertia Indicator.

per cent., and as only half of the weight of the crane comes on its drivers the maximum traction would appear to be about 12½ per cent. of the whole weight. Something should be deducted from this in starting, and the same amount added in stopping, for the journal friction in the trailing wheels; but as long as the drivers do not slip the effect is surely less than the maximum possible, and, therefore, I had assumed 10 per cent. of the weight as a rough and ready approximation to the horizontal force in question.

I knew, however, that traveling cranes do sometimes get out of square, and to be sure that the runway under consideration was not deficient in lateral strength, it was important to demonstrate in a practical way the actual force of inertia to be anticipated.

It was suggested by my colleague in the work that this force might be estimated from a determination of the space and time required to stop a crane running at full speed, and, accordingly, experiments were made on the most available crane at our command with this end in view. A chalk line was drawn on the wall of the building, and at the instant of passing this line at full speed the operator was instructed to stop the crane as quickly as possible. An observer with a stop-watch noted the time in stopping, and the distance traversed beyond the chalk line was measured. These experiments indicated, as I remember, that the horizontal force exerted in stopping was about 15 per cent. of the moving weight—a value that accorded well with the maximum frictional resistances assumed. The method, however, necessitated simultaneous action and observation by two or more participants, and, as the time was measured in seconds and fractions, there was apparently room for considerable error in the result, by reason of personal differences in precision.

It was doubtful, also, whether the retarding force could properly be considered as uniform during its period of action, and even the yielding in the runway to the force put upon it seemed to claim some consideration. It then occurred to me that a pendulum attached to the crane would tend to indicate by its position the horizontal force applied, but a difficulty at once appeared in controlling its vibrations without affecting the accuracy of the readings desired. A pendulum necessarily has weight, and in moving quickly it would surely acquire momentum tending to make it overrun its true position. Endeavoring to avoid this difficulty, it then occurred to me that a spirit-level is really an inverted plumb-bob, and that in the air-bubble I had, practically, the pendulum without weight that I wanted.

To indicate horizontal forces I could easily give the tube the necessary curvature and graduate it. Accordingly, I had an instrument made and graduated in degrees from which the tangent of the angle could be taken for the horizontal force required. A later form of the instrument, here exhibited, is graduated, not in degrees, but in a scale of tangents, so that the horizontal force is read at once in terms of the weight moved. No special care is required in its construction because the method of graduating takes care of any irregularities that may exist in the curvature of the tube. It is important, however, that the size of the air-bubble be proportioned to the size and curvature of the tube employed. A large bubble has some tendency to distort and overrun the mark, while a small bubble is unnecessarily sluggish in its movement. A bubble of the proper size will be quick and accurate.

On traveling cranes this indicator has shown effects ranging from 2 to 15 per cent., depending upon the method of driving. Power applied through friction clutches is more sudden in its action than a motor directly coupled, and the resistances used in the starting-box naturally affect the acceleration or retardation of the motor.

In steam or trolley cars the indicator may be laid in the window-sill in the direction of motion, and the force used in starting or stopping will be shown. In these cases a correction is often required for the grade of the track, which can be read off when the car is at rest. On way trains the force used in starting is about 3 per cent. and in stopping about 12 per cent., while on trolley cars about 12 per cent. of the weight is used both in starting and in stopping. The indicator shows at all times the effective accelerating or retarding force, and when the speed is constant the bubble stands at zero. As applied to traveling cranes, the sway of the runway is included in the result observed, and no corrections need be made. A swinging load introduces some uncertainties, but the maximum disturbance from this cause will probably not exceed that of the same load rigidly attached.

Other uses for the indicator might be suggested, but enough has been said to illustrate its application, and as a new and convenient device for measuring inertia effects it has been thought of sufficient interest to bring before the Club this evening.

DISCUSSION.

James Christie.—Mr. Lewis is to be credited for this simple and ingenious instrument, which evidently fulfils its object admirably. Its compactness and portability are not its least merits. Referring to the bridges of traveling cranes and the large mass of material in motion, it became customary, after the application of the electric motor to this class of tools, to use the magnetic brake on all the motors of the crane. This brake acts instantly when the current is cut off the motor. The action is not only severe on imperfectly braced runways, but also on the traveling mechanism of the crane. It has, therefore, been found better to omit the magnetic brake for this instrument, and to substitute a manual brake, controlled by the operator, who graduates the brake pressure according to circumstances.

ABSTRACT OF THE MINUTES OF THE CLUB.

BUSINESS MEETING, February 5, 1898.—The President, L. Y. Schermerhorn, in the chair. Eighty-one members and visitors present.

The election of George E. Dadmun, Richard G. Develin, Thomas A. Edison, S. W. Evans, Edgar C. Felton, Theo. W. Johnson, James C. Newlin, and Alfred Walter, to active membership, A. G. Sparks to associate membership, and R. D. Coombs, Jr., to junior membership was announced.

The special committee on New Club House was continued, except that W. C. Furber was appointed chairman.

Gen. Roy Stone, Director Office of Road Inquiry, Department of Agriculture, presented a paper entitled, "Various Phases of the Road Question." The subject was discussed by Messrs. Schermerhorn, Budd, Huidekoper, Rose, Townsend, Janvier, Franklin, and Chance.

REGULAR MEETING, February 19, 1898.—The President, L. Y. Schermerhorn, in the chair. Sixty-two members and visitors present.

Mr. Francis Schumann read a paper entitled, "The Dome of the City Hall Tower." The subject was discussed by Messrs. Schermerhorn, Nichols, and Birkinbine.

BUSINESS MEETING, March 5, 1898.—The President, L. Y. Schermerhorn, in the chair. Eighty members and visitors present.

Mr. Benjamin Franklin read a paper entitled, "The Inspection of Buildings." The subject was discussed by Messrs. Marburg, Christie, and Richards.

The election of Messrs. H. S. Hayward and Leighton Lee to active membership, and H. A. Schaffer to junior membership was announced.

The following resolution was offered :

That the question of the water supply of Philadelphia be referred to the Committee on the Relations of the Engineering Profession to the Public, to report on the action necessary to secure an adequate and wholesome supply under city management ; also the desirability, if any, of leasing in whole or part the water-works.

On motion, the resolution was amended by striking out all words after the word "management," and inserting after the word "report" the words "to the Club." The resolution thus amended was adopted.

REGULAR MEETING, March 19, 1898.—The President, L. Y. Schermerhorn, in the chair. Seventy-three members and visitors present.

The meeting was devoted to a topical discussion on "Modern High Explosives," by Messrs. Schermerhorn, Falkenau, Ott, Nichols, Eglin, and Prince.

REGULAR MEETING, April 2, 1898.—The second Vice-President, Wm. C. L. Eglin, in the chair. Sixty-five members and visitors present.

Henry Leffmann presented a paper on "The Engineering Chemistry of Boiler Waters."

The subject was discussed by Messrs. Birkinbine, Nichols, Ledoux, Landis, Christie, Hartley, Coffey, Twining, and Furber.

Business Meeting, April 16, 1898.—The President, L. Y. Schermerhorn, in the chair. Sixty-two members and visitors present.

The tellers reported the election of Messrs. C. M. Broomall, James S. Doran, David Halstead, Jr., Geo. P. McArthur, H. B. Nichols, Arthur E. Paige, David Pepper, Jr., E. Percy Teal, and J. H. Vail to active membership ; Messrs. L. V. Clark, Jr., Samuel C. Dinsmore, and W. H. P. Fisher to associate membership ; and Messrs. Herman Livingston and Irving B. Smith to junior membership.

Mr. J. W. Ledoux read a paper entitled "The Deep-well Pumping Plant at Waukesha, Wis."

The subject was discussed by Messrs. Christie, Livingston, Nichols, Dallett, Trotman, Birkinbine, Falkenau, and Trautwine.

Mr. Wilfred Lewis exhibited and explained a new "Inertia Indicator." The subject was discussed by Mr. Christie.

ABSTRACT OF THE MINUTES OF THE BOARD OF DIRECTORS.

Special Meeting, February 6, 1898.—Present : The President, the Vice-Presidents, Directors Schumann, Humphrey, and Smith, the Secretary, and the Treasurer.

The meeting was called to consider certain questions in regard to the business of the Club, and especially to elect a director for the unexpired term of Mr. Wm. C. L. Eglin,—Mr. H. C. Luders, who had been elected to that position, having been obliged to decline. Mr. Minford Levis was elected to the position.

The resignation of Mr. Jones Wister was accepted, to date from December 31, 1898.

Regular Meeting, February 19, 1898.—Present : The President, the Vice-Presidents, Directors Hartley, Schumann, Levis, Humphrey, Ott, and Smith, and the Secretary.

The Treasurer's report showed balance on hand, January 31, 1898, $2150.96.

The Library Committee was awarded an appropriation of $100 for binding, subject to the approval of the Finance Committee. Appropriations were made to the House Committee for various house improvements.

Regular Meeting, March 19, 1898.—Present : The President, the Vice-Presidents, Directors Hartley, Schumann, Levis, Humphrey, and Smith, and the Secretary.

The Treasurer's report showed on hand, February 28, 1898, $2366.90.

Resignation of active membership was presented and accepted from Mr. Wm. H. Francis.

The Finance Committee reported approval of the various appropriations made to the House and Library Committees.

Regular Meeting, April 16, 1898.—Present : The President, the Vice-Presidents, Directors Hartley, Schumann, Levis, Humphrey, and Smith, and the Secretary.

The Treasurer's report showed the total receipts for January, February, and March,	$2922 10
Balance, December 31, 1897,	630 51
	$3552 61
Total expenditures,	1875 55
Balance, March 31, 1898,	$1677 06

The Secretary reported that he had procured a corporate seal for the Club.

The Finance Committee presented a written statement of receipts and expenditures from January 1st to March 31st; also a statement of expenditures for 1897 and an estimate of the probable expenditures for 1898.

The Library Committee reported the binding of a considerable number of books, especially including transactions of engineering societies.

The Committee on New Club house reported that it is collecting information on the subject, but has not yet obtained necessary data for a comprehensive report.

CONTRIBUTIONS TO THE LIBRARY.

From Benj. Smith Lyman.

Compass Variation Affected by Geological Structure in Bucks and Montgomery Counties, Pa.—Lyman. The Gradienter—Lyman. The Future of Japan in Its Relations with China and Russia—Lyman. Against Adopting the Metric System—Lyman.

From Field Columbian Museum.

Annual Report—1896-97.

From United States Coast and Geodetic Survey.

Annual Report of the Superintendent of the Coast and Geodetic Survey for the year 1896.

From the Commissioner of Patents.

Annual Report for year 1896.

From the Academy of Science of St. Louis.

Transactions, Vol. VIII, No. 1.

From Smithsonian Institution.

Proceedings and Transactions of the Nova Scotian Institute of Science, Vol. IX, Part 3, Session of 1896-97.

From American Institute of Mining Engineers.

The Michigan College of Mines—Wadsworth. The Origin and Mode of Occurrence of the Lake Superior Copper Deposits—Wadsworth. Some Statistics of Engineering Education—Wadsworth. The Efficiency of Built-up Wooden Beams—Kidwell. Emery, Chrome Ore, and Other Minerals in the Villayet of Aiden, Asia Minor—Thomae. The Influence of Antimony on the Cold Shortness of Brass—Sperry. A Study of the Elimination of Impurities from Copper Mattes in the Reverbatory and the Converter—Keller. An Automatic Feed Device for Gas Producers—Bildt. Note on Limonite Pseudomorphs from Dutch Guiana—Raymond. The Ultimate and the Rational Analysis of Clays and their Relative Advantages—Ries.

FROM THE ASSOCIATION OF RAILWAY SUPERINTENDENTS.

Proceedings of the Seventh Annual Convention of the Association of Railway Superintendents of Bridges and Buildings, October 19, 20, and 21, 1897.

FROM THE WAGNER FREE INSTITUTE OF SCIENCE.

Transactions, Vol. V, January, 1898.

FROM THE ENGINEERING ASSOCIATION OF THE SOUTH.

Proceedings, March, 1898.

FROM THE ALABAMA INDUSTRIAL AND SCIENTIFIC SOCIETY.

Proceedings, Vol. VII, Part 2.

FROM THE UNITED STATES GEOLOGICAL SURVEY.

Irrigation in Messilla Valley, New Mexico—Barker.

FROM THE AMERICAN SOCIETY HEATING AND VENTILATING ENGINEERS.

Transactions, Vol. III.

FROM B. F. STURTEVANT CO.

Treatise on Mechanical Draft.

FROM THE INSTITUTION OF CIVIL ENGINEERS OF IRELAND.

Transactions, Vol. XXVI.

FROM THE ENGINEERS' CLUB OF ST. LOUIS.

Third Annual Bulletin, 1898.

FROM UNITED STATES GEOLOGICAL SURVEY.

Stream Measurements, by Arthur Powell Davis.

FROM WAR DEPARTMENT LIBRARY.

Monograph upon Reservoirs and their Effects on the Floods of the Mississippi System, by James A. Seddon.

FROM ENGINEERING ASSOCIATION OF THE SOUTH.

Proceedings, Vol. IX, No. 3.

FROM AMERICAN INSTITUTE OF MINING ENGINEERS.

An Apparatus for the Removal of Sand from Waste Water of Ore Washers—Johnson. Mining Districts of Colombia—Granger and Treville. The Kotchkar Gold Mines, Ural Mountains, Russia—Nitze and Purington. Kalgoorlie, Western Australia, and Its Surroundings—Bancroft. The Relation of the Strength of Wood under Compression to the Transverse Strength—Fernow. Some Dike Features of the Gogebic Range—Discussion. The Accumulation of Amalgam on Copper Plates —Discussion. Proceedings of the Seventy-fourth Meeting, Atlantic City, N. J., February, 1898.

FROM CANADIAN SOCIETY OF CIVIL ENGINEERS.

Transactions, October–December, 1897.

FROM CHIEF OF ENGINEERS, UNITED STATES ARMY.

Annual Report, 1897, Six Parts.

FROM NORTH OF ENGLAND INSTITUTE OF M. AND M. ENGINEERS.

An Account of the Strata of Northumberland and Durham as Proved by Borings and Sinkings.

NOTES AND COMMUNICATIONS.

OBSERVATIONS IN GREENLAND.

At the Conversational Meeting, held April 9, 1898, Dr. Henry E. Wetherill, surgeon to the Peary relief expedition, exhibited and explained a series of lantern slides illustrating the geology, natural history, and ethnology of Greenland.

He pointed out the racial differences between the Eskimos of different parts of Greenland; in some sections there is a considerable admixture of Scandinavian blood. Habits of life, methods of house construction, etc., were briefly outlined. Some of the weapons and accoutrements were also shown.

Many illustrations of the great glaciers of Greenland were exhibited, and their relation to the formation of the icebergs of the North Atlantic pointed out.

Dr. Wetherill also exhibited several forms of compact scientific apparatus especially adapted for use in very cold regions; also some miscellaneous apparatus for the preparation of food and for exigencies of travel.

ERRATA.

Attention is called to the following errors in volume XV, No. 1, of the Proceedings:

Page 4, line 18, $946,414,665 should be $946,314,665.

Page 42, the title of the cut, read 10,000 instead of 1000.

Page 69, line 2 from bottom, the denominator of the fraction should be $1 + 2 \cos^2 45°$.

Page 70, line 3, for V read v; for c read C; for $\frac{M}{D}$ read $\frac{M}{b}$.

" " 2 from bottom, for Z read z.

Page 71, line 3, for X read x.

" " 4, for Z read z and for k read k_n.

" " 6, for Y read y.

Page 72, line 10, for W read w; for Y read y.

" " 11, for P read p.

Page 76, line 2 from bottom, read Mueller Breslau for Mueller of Breslau.

Editors of other technical journals are invited to reprint articles from this journal, provided due credit be given the PROCEEDINGS.

PROCEEDINGS
OF
THE ENGINEERS' CLUB
OF PHILADELPHIA.

ORGANIZED DECEMBER 17, 1877. INCORPORATED JUNE 9, 1892.

NOTE.—The Club, as a body, is not responsible for the statements and opinions advanced in its publications.

Vol. XV. JULY, 1898. No. 3.

A CASE OF JURISPRUDENCE IN LAND SURVEYING.

AMBROSE E. LEHMAN,
Civil and Mining Engineer.

Read May 7, 1898.

SOME years ago the writer, in the course of his experience as a civil and mining engineer, became familiar with an extensive land survey involving an interesting question of jurisprudence.

An old and well-known mining and iron corporation, possessing a large and valuable tract of land in a neighboring State, desired a thorough survey of its boundary lines. The tract consisted of some thirty square miles of land, exclusive of several outlying tracts.

Having no idea what the cost of such a survey would be, the company made their needs known and solicited bids from a limited number of engineers whose record of experience warranted confidence in their ability to do such work. As will be seen further on, the operations of the work required something more than an ordinary surveyor, however experienced and thorough he may have been as such; because results were desired the determination of which would come properly within the scope of a civil or topographic engineer. Here it may be well to mention the distinguishing quality between the capacities of the professions of civil engineering and land surveying. In many sections of our country the civil engineer is confused with the land surveyor and their titles are understood to be synonymous; particularly where the work of the surveyor, only, is in demand. Popular knowledge on this subject seldom teaches the fact that, while a land surveyor is not necessarily an engineer, or capable of solving his problems, an engineer, civil or topographic, at all worthy of his profession usually possesses better theoretic knowledge, more skill in the use of instruments, and is and must always be capable of making land-line surveys with scientific accuracy. Perhaps the only distinction to be mentioned in favor of the surveyor of experience is his greater knowledge of the art of woodcraft. This in many cases is an important desideratum.

To return to our subject, the engineers invited to examine and bid on the work to be done did so. One of the number, after going over the ground with due consideration of the points observed, fought shy of the whole or any part of the undertaking and declined to bid. He was the only one of the number who was at all familiar with work in the section of country in which the property was situated. Another submitted a proposition, but his terms were so unreasonable that they were not seriously considered. Still others put in bids for the work, but, for reasons not necessary to mention, they were not given an opportunity to experience the disappointments and tribulations that befell the engineer to whom the contract was finally awarded.

The contract entered into between the engineer and the company was, in substance, as follows:

It was understood that a survey was to be made of all the property belonging to the said mining and iron company, which survey should include the following features:

First. The establishment of a true north and south line at some suitable point on the property.

Second. The survey of the outside boundary line of the property, including the outlying lots.

Third. The location of all houses, buildings, mines, lakes, ponds, principal roads, and streams; the lineal amount of roads to be surveyed not to exceed the amount shown on an old map of the property, and the lineal amount of streams to be surveyed not to be less than thirty miles.

Fourth. The principal features of the topography as far as the same are incidental to the surveys above mentioned.

Fifth. A finished map of the whole work in all its details, on a scale of not less than six inches to the mile.

It was further understood that the engineer would begin work on a certain date, and would continue the same to completion, giving at least two-thirds of his entire time to it. Through all said portion of the time during which work was prosecuted on the property the engineer would personally superintend the same.

Then follows the terms of compensation to the engineer; a lump sum based on so much an acre that the property was supposed to contain. In these terms it was agreed that the engineer was to draw on the company for his actual cash outlays in accomplishing the work, and the balance of the total sum to be paid upon its completion and approval of the same by the company.

A supplementary agreement was made, in verbal form, however, relating to the possible passage of the boundary line through a lake said to comprise valuable boating and fishing grounds. The corporation was so anxious to include a portion of said lake in their territory that they were willing to "gamble" on a liberal sum to the engineer, should he find they had any claim to its waters. To dispose of this point, the surveys subsequently proved that the company had no such claim, and never had. The expense of doing the work, in accordance with the terms of the contract, was calculated on the basis of information obtained from several old and not very reliable maps and plots of the whole or portions of the property, descriptions given in the title papers on record, and a hasty reconnaissance of the land itself, accompanied by the overseer of the properties, whose knowledge of their boundaries and monuments governing same was supposed to be full. This knowledge and his general assistance in the surveys during their progress were pledged to the engineer by the company.

Before beginning actual operations in the field a careful analysis of the whole problem was made. The main tract, whose circuit measured about 44 miles, was found to be of very irregular shape, 11 miles long and about 4 miles wide, with a trend northeast and southwest. The circuit of the outlying lots combined was 18½ miles. A very careful plot of the properties as a whole was attempted, guided by the minutest details given in the records. It was then discovered that few of the circuits would close, the discrepancy in the main tract being enormous,—as much as 2½ miles. The courses and distances in the deeds of record on file in the county office were inaccurate and misleading. Besides these errors in bearings and dimensions, several were lacking altogether, and the construction of a rough plot of the whole property would have been possible only through powers of divination of what was intended, and not by what was recorded. There was an absence of any record of the date of the surveys described in the original deeds, or of any notice of magnetic variation at that time.

In the next step, preliminary to beginning field work, the property itself was explored in detail. The country was found to be unusually rugged and mountainous, with very sharp contrasts, from low, swampy lands to sudden and extended elevations. The most pronounced features of the topography consisted of numerous rock-capped ridges, perpendicular cliffs, and several impassable swamps. Three lakes of considerable area and several ponds of varying size gave greater expression to the topography, and had to be dealt with especially during the progress of the survey. For the most part the country was thickly wooded, and in many places a dense tangle of underbrush stood as an obstacle to easy work. Though the areas of arable lands were quite limited, a close acquaintance with the property disclosed much mineral wealth in the form of rich, magnetic iron ores. These deposits were distributed here and there throughout the region, some of which were extensively developed and successfully mined, for many years supplying ores to neighboring furnaces and to the general market. These deposits were destined to play a conspicuous and very important part in the survey of the property. The fact was soon discovered that their influence would be felt in the form of local attraction generally throughout the territory, and enter as a serious and important factor in the work.

It was quite apparent that the value of the property did not depend alone on its mineral deposits. The region was peculiarly picturesque and interesting,—within forty miles of one of the largest centers of population, and hence valuable for country homes of the wealthy. This was attested by imposing residences and expensive improvements within view on adjacent lands.

After deciding upon the point of control for the survey, the work was begun, and early in its progress it became evident that, owing to the very abrupt changes in the contour of the ground, precise methods of admeasurement were necessary; and, owing also to the all-pervading local attraction, these conditions required the use of a theodolite, and all angles measured with the vernier, totally disregarding the needle excepting for the purpose of checking the angles measured.

It was not long before the engineer discovered that among the company's employees not one possessed sufficient knowledge of the boundaries and corners to render much assistance in finding them. To seek them by the recorded courses and distances was impossible because, as before mentioned, to follow these directions in many cases was sure to lead one astray. The reason for this was explained by the character of the original surveys and land grants. These lands were patented to the original owners in the form of lots, the division lines of which were intended to be perfectly straight and parallel, bearing approximately northeast and southwest. However, that these lines were tangents and parallel, when laid down, was more imaginary than real, because, having been surveyed entirely with the compass, regardless of the ever-potent, local attraction of the needle, they necessarily became lines of varying direction every time a new position was taken by the compass.

The history of the company's property and an examination of its archives brought to view crude maps and brief descriptions of three different surveys. But they all furnished very meager data and bore evidence of being based on "Jacob's staff" compass work. The sections of the property that grew by purchase of adjoining tracts, when plotted from notes of resurveys, preliminary to such purchase, would not close with themselves, nor would they fit the lands to which they were to be joined. These and other details are mentioned merely to show how utterly unreliable, false, and misleading much of the information about the lands was. The engineer found, as he extended his lines, that the knowledge thus obtained from the ground itself of the confines of the property was no more satisfactory than that to be had from the company's archives. There were few lines or witness-trees to mark the boundaries, because they had long ago disappeared with the wood converted into fuel, used for smelting the iron ores. The small number left standing by the wood-choppers was afterward destroyed by the fires that occasionally swept through the subsequent growths of timber.

The monuments originally marking the corners of the property consisted mostly of stones loosely thrown together around a stake driven into the ground. These monuments were frequently missing entirely, or moved to a wrong position.. In some cases, at important corners, a group of two, three, or more stone heaps marked points where repeated surveys, by as many different surveyors, had fixed, as they supposed, the true position of the monument. And so, as the work proceeded, the conditions governing it gradually presented themselves, and the best method of running the lines from corner to corner was therefore suggested. The theodolite was set up at the point of beginning of the line to be traced, and the telescope placed in line with the bearing prescribed by the deed. Allowance for magnetic variation was seldom made, for the reason that local attraction, being so general (its strength varying from zero to twelve or more degrees), it was not worth while to pay any attention to this factor. The line thus started, it was extended as a tangent the required distance toward the next corner. Of course, when this was measured the point sought was seldom found where, theoretically, it was expected to be. When finally discovered, its exact position was located by a side-line to the right or left as the case required. From the point thus fixed the next required course was started toward the corner next in order; and so the work proceeded. It was a constant groping in the dark. The lines as actually surveyed were necessarily random lines only, and the azimuth occurring between them and the true lines as they should have been laid down, had it been possible by the first running, was, of course, always an unknown quantity until the real course was ascertained.

Through unsuccessful trial lines, attempts to locate monuments that had long been extinct, confusion caused by a multitude of evidence in the shape of two or more stone heaps where only one was required, and the consequent doubt as to which was the correct one, much time was lost and the surveys became tedious and laborious beyond calculation. While the survey of the outside boundary lines was in progress, the interior work was carried on with the same care and precision as the methods used in the boundaries required. In both the measurement of distances was repeated; all angles were noted twice by recording the readings of the two verniers on the transit, and the bearing of every sight was taken twice, first forward and then backward. The interior lines were used as a check to insure the accuracy of the exterior work by the numerous circuits thus made. For topographical purposes levels were taken by vertical angles. All distances were measured by stadia.

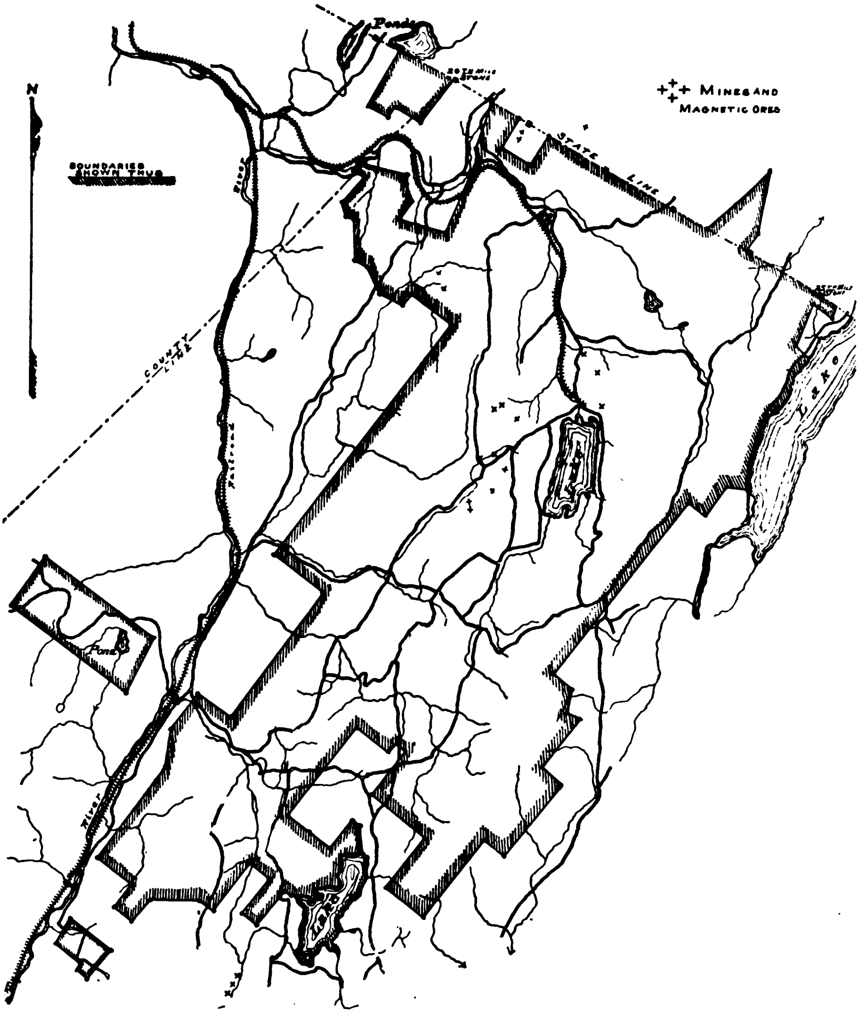
The limits of the property, to the extent of several miles, were marked by the shore line of two lakes, and in several cases the ground was so swampy and unsteady that it was deemed expedient to postpone work here until the winter season, when the surface of the lakes would be frozen sufficiently solid to permit surveys thereon.

I desire to remark here that this description of the minutiæ of the work done is justifiable only that it may assist to a full comprehension of the points involved in our subject.

At the agreement made between the engineer and the company, the latter endeavored to have a time-limit fixed within which the work should be completed. They suggested that three months would accord with their ideas as to the time required to accomplish the job. The engineer knew that this was impossible, and with the uncertainties ahead, and the knowledge of the impossibility of adopting beforehand fixed methods of doing the work (the country was a *terra incognita* to him), he declined to be held down to any certain time. He resolved to "proceed as the way opened," and as the undertaking was rather a formidable one, and would probably open new questions and require the solution of problems unusual in the simple running of land lines, he worked with more than ordinary interest and energy to hasten its scientific and practical results.

In due course the job was accomplished. A total of over 300 miles of line had been run; surveys were calculated, acreage estimated, and map drawn. The latter was constructed on a scale slightly larger than the contract specified, and in all its features filled its requirements. The outside lines were shown and tinted, the bearings and distances given, and the corner monuments were described with characteristic detail. The roads and streams were drawn and colored in appropriate tints; along all lines of survey a belt of topography, varying in width from 400 to 500 feet, was shown. In every way possible, so far as the map was concerned, the terms of the contract were complied with, and so acknowledged by the company.

The whole undertaking had consumed over a year's time. During



the progress of the surveys, and when about half accomplished, the company refused to make any further cash advances on account of expenses, on the plea that the period of time through which the work was dragging was unreasonably long, with, as yet, no definite results. The engineer, nevertheless, continued to push operations to completion, providing funds for field expenses from his own means, notwithstanding that he already saw he was destined to be a heavy loser in the end.

As promptly as possible the finished map was delivered to the company, accompanied by a report describing at length and in detail the lines surveyed, the character of the corner monuments and surroundings, landmarks in general, the difficulties encountered in the work, and causes of the various delays in arriving at final results, together with full information incident to the surveys and how they were conducted. At this time a request was made by the engineer for a final and full settlement according to contract. This request was refused, with the reply, on the part of the company, that no further payments would be made for the following reasons:

First. That the delivery of the map and results of the work were unreasonably long delayed and had caused disappointment and embarrassment to the company.

Second. That the lines run did not show on the ground the actual boundaries, and were misleading as to where the true lines of the property really stood.

Third. That the contract bound the engineer, though this was not explicitly stated; yet the very essence of the contract bound the engineer to lay down on the ground the actual and true lines from corner to corner, after he had ascertained their position, by setting stakes and cutting a vista through the forest and underbrush.

Fourth. That the true north and south line established on the property did not show the magnetic variation of the locality.

Fifth. That where no corners were found, whether they had become extinct from natural causes, been destroyed or removed to wrong positions, the engineer should have restored them to their proper place.

Sixth. Though the map furnished was an artistic piece of work, bearing evidence of care and precision in its construction, and in all probability accurate at all points, yet it merely showed, theoretically, where the lines of the property were, and would not serve as a guide by which they could be traced on the ground.

Seventh. That all notes, note-books, plots, papers, calculations, etc., of whatever nature, incident to the prosecution of the surveys, rightfully belonged to the company, and were wrongfully retained by the engineer.

In the latter's protest against such an unjust view of the situation, he replied to their propositions as follows:

First. That the delay caused by the difficulties encountered in the work were not of his making and were entirely beyond his control. That the thorough methods employed required time and every precaution taken to guard against error and hasty conclusions, while, in the end, all were for the company's benefit; at the same time the care and safeguards taken by the engineer caused him a constantly increasing expense. The truth compelled him to say that he was led into a misapprehension of the difficulties and impossibilities attending such a survey, and that the company, on its part, had not done what was promised to assist him in finding the boundaries. That the work might have been prosecuted with great vigor and display with a large force in the field; lines established on the ground with the merest approximation to where they belonged, a handsome map drawn and delivered, all within a remarkably short time; yet, nevertheless, everything be unreliable and misleading. Such results might have been accepted and paid for, and only when another engineer had been employed to test the surveys, by rerunning the circuits, could their real character be known.

Second and Third. That to lay down the lines in their true position and cut a vista through the forest, around the whole property, would necessitate the doing of the work over again, at almost the same cost of the original surveys, and this the engineer held he was not legally bound to do, and still less inclined to do, owing to the serious loss sustained in the completion of his contract.

Fourth. That the establishment of a line on the property, astronomically north and south, was performed and substantially staked out, but, due to the ever-present and inimical element, local attraction, the angle of magnetic variation from true north could not possibly be ascertained within reasonable time and expense.

Fifth. That where corner monuments were missing because of the doubtful authority conveyed by the records, the engineer was in nowise bound to restore them under such circumstances. That to do so on no basis of agreement between adjoining property-holders would be to assume judicial functions clearly foreign to his duties in this case.

Sixth. That the map furnished the company could, under the circumstances, be nothing more than an exhibition of the conditions found on the ground, exactly as they were. But, it must be remembered that the topography shown on the map would point to indestructible landmarks by which the boundaries could be traced.

Seventh. That as the whole work was done by contract, for a stated sum, the engineer was bound to furnish nothing more than what his agreement strictly called for and the results desired by his employers. On these grounds it was held that his methods and records belonged to him, as long as results given were accurate.

The position taken by the company was not long maintained. The refusal to pay the engineer was made by the president, who was a lawyer, and evidently unable to take any other than a strictly legal view of the case. The engineer appealed from his decision, which in the end brought about a settlement in accordance with the contract. The balance due him was paid, and when all salaries, wages, and expense accounts were settled, he found, in confirmation of previous fears, he had lost seriously on his job.

We have now come to the main point of our subject. An attempt has been made to touch the questions of jurisprudence involved in the case described, and, as here presented, what conclusions may follow its consideration, and by what process of reasoning they will be formed. One may ask, What constitutes a complete survey and map of a property? Naturally an engineer or surveyor would answer this question in accordance with the dictates of his education, experience, and general field training. The purposes of the survey, the terms on which the engineer is employed to perform the work, and his rate of compensation must be allowed some weight in the answer to this question. It is clear that land-owners, in their ignorance of the elements of surveying, have no right to demand what is technically and practically impossible to accomplish.

In the case just cited, however prejudiced our view may be in favor of the company, in their contention that the engineer could not fulfil his contract short of restoring the boundary lines of their lands as they originally were surveyed, in harmony with the courses and distances, metes and bounds, as given in the deeds of conveyance; yet, such a view of the case must certainly allow the engineer, on *his* part, to demand of his employers that they provide him with a correct record of the field-notes of these surveys, in full and exact detail, showing where every position was taken by the instrument used, its character and equation, the exact positions occupied, and length of every sight; for without these exact data it would be manifestly impossible for him to reproduce the original results or lay down the lines as they were before all signs and vestige of their position had disappeared. On these grounds alone he possessed a strong case in his favor, sufficient to exempt him entirely from further effort and loss.

The perturbation of local attraction upset all his calculations and followed him like a Nemesis all over the territory traversed.

To an engineer or surveyor that has had a similar experience, there has doubtless occurred various suggestions bearing on points touched in the case just described. What could have been done to prevent, or what can now be done to remedy, in some measure at least, the execrable methods commonly used in tracing, establishing, and recording land boundaries? With few exceptions there appears to be no definite regulation, system, or law in the United States leading to the performance of thorough and scientific work or correct results and records in this line. Incompetent hands and inefficient methods are seen to rule on all sides. Next to medical jurisprudence, first because it involves questions of human life, stands engineering and land surveying jurisprudence, since, though it does not necessarily touch life itself, it does involve questions of property and values, frequently in large amounts, exclusive of the time and trouble expended in prolonged litigation over property lines erroneously laid down, with additional errors in the records.

Why the lack of a strict system to govern work of this nature has been allowed to prevail, practically since our country was settled, seems incomprehensible; and that there appears to be little disposition to bring about any improvement, considering all the subject involves, is still more inexplicable. Assuredly some good system could be devised to correct present evils, to the end that future records of land divisions might be less open to dispute and costly litigation. Under better conditions such disputes would naturally be adjusted by surveyors, being within their functions, provided they were really fitted for their duties by education and experience; and not by lawyers and courts; for, after all is said, any reasonable settlement could necessarily be reached only along lines wrought out by a competent surveyor, and facts established by him.

The practice of the profession of civil and mining engineering and land surveying should be regulated in precisely the same manner as are the professions of medicine, pharmacy, law, etc. The duties of the engineer and surveyor frequently involve questions of too much importance and value to permit their being intrusted to persons whose ability and experience have not had the official indorsement of properly constituted authorities and judges. While some such system has been followed to a degree by municipalities, yet few, if any, of our Eastern States, particularly where land is most valuable, have as yet enacted any statutes regulating the practice of land surveying and civil engineering.

It is not intended at this time to formulate any particular methods through which improvements may come, but it is clearly within the range of the ordinary mind to conceive some way by which persons wholly unfitted to approach such work might be prevented from even attempting to determine questions pertaining to limits between landholders. The least that should be done in recording land-title papers in the county records would be a law compelling a plot to accompany every survey of land described, showing graphically the form of the land conveyed in the deed; said plot showing, beyond question, that the circuit made will close correctly, according to the courses and distances given, and to be filed as a necessary part of the deed.

DISCUSSION.

E. M. Nichols.—What instruments were used in making those surveys?

Mr. Lehman.—Regular theodolites with vertical circles, and the acreage was estimated by the usual surveyors' methods, and afterward checked with the planimeter. The whole circuit involved more than one hundred sides.

Benjamin Franklin.—Was the survey made by traverse? What percentage of error was found?

Mr. Lehman.—The survey was made by running random lines as nearly as possible in accordance with the bearings given in the land deeds. A few years before the survey was made the monuments were removed along the State line, and after a very careful relocation of the line new ones were set a mile apart. The report and map of this survey indicates very careful work. The surveyor of the property in question used the stadia system of measurement. It was the only way of doing the work satisfactorily, because the territory was so precipitous that chaining would have taken a considerable time, and would have required experts, since it may safely be assumed that no ordinary man can break a chain properly.

MR. FRANKLIN.—Comparing stadia and chain measurements, the percentage of error, I believe, would be about the same; if anything, slightly in favor of stadia. In a survey of this kind I consider it totally unreliable, whether local attraction exists or not. I invariably use one well-defined, undisputed line as a base, and turn off my angles from that, using a vernier. When an old corner is indicated by one or more monuments or points, it is generally impossible for the engineer to make a definite and reliable location by running the lines according to the deeds or old plans. The best method, in my judgment, is to establish such a corner by an amicable agreement with the parties affected, the engineer furnishing the data required.

MR. NICHOLS.—What was the longest mile found?

MR. LEHMAN.—I think they were mostly short. The longest mile measured was 5227 feet. There had been a great deal of surveying in this neighborhood, and there were records going back fully as long as anything we have in this State, and the general discrepancies of the land lines in that country were caused by the crude methods then used. I do not think that is sufficient excuse, because I had occasion on the geological survey, many years ago, to trace up many miles of Mason and Dixon's line, and found it thoroughly well done and fully up to the standard of good work to-day. It showed that the instruments then in use were capable of doing good work. It was not that good work could not be done in those days, but the surveyors, in their ignorance, attempted to do things which they did not understand.

J. SIMPSON AFRICA.—I am almost ashamed to participate in this discussion, as I have been absent so long from the meetings of the Club. I listened with great interest to the paper, and think the author presents this difficult subject in a very able manner, and that he deals with the question in a scientific way. I can not refer to the details of the work, as he has not given them to us. On one point I would differ from him. I hold that it is the business of the surveyer to locate and mark the lines on the ground. Of course, the contract may in this case not have required that.

Local attraction nowhere affects the compass-needle in Pennsylvania, except in parts of Adams County. Where surveys have been carefully made with the compass the surveyor who keeps himself posted in the declination of the needle can retrace the lines with a remarkable degree of accuracy. I can not say anything further on this particular subject other than to commend the surveyor for the industry and skill shown in his investigations.

THE PRESIDENT.—As I understand the matter, it became a problem to reproduce the corners as they were originally placed.

MR. LEHMAN.—Yes; or the landmarks which would fix the land lines between the corners.

THE PRESIDENT.—I believe, in the survey of public lands, the object is to fix the corners as originally located, regardless of the fact whether they were correctly located or not. Does that principle apply to these lands?

Mr. Lehman.—It does not. We have, unfortunately, in the Eastern States no regulations or system at all, and I think we should, especially in the Atlantic States, where land is valuable, have regulations which would not only guide in the work of such surveys as that, but require the employment of competent men. They could be licensed, just as a druggist or physician is. If that were done, we should have very much less litigation in the work of boundary-line surveying.

Mr. Franklin.—Is there not a law in this State bearing on that subject?

Mr. Africa.—Yes; the law bears directly on the subject. If an original corner or line can be found, you must extend the survey to it, whether the distance be long or short. Mr. Lehman spoke of the Mason and Dixon line as being an accurate astronomical line. I never tested it, but believe it to be so. The marking of the New York line was not accurate. A resurvey of that line was authorized by the respective States a few years ago. The initial point was fixed by David Rittenhouse late in 1774, and, the Revolution soon coming on, further progress was abandoned until in the '80s, when work was resumed and the line extended to Lake Erie, and stone monuments placed at intervals of some miles. On a resurvey made some years ago most of the stones were found out of place, some of them as much as a quarter of a mile. One of the commissioners urged that these marks should be ignored and the true parallel of 42° observed. I chanced to occupy an official position at the time, and took the ground that these marks must be adhered to, whether they did or did not stand on the true line of 42°; that we had no authority to correct them, and, besides, each State had sold land up to the line marked by the original monuments. The commissioners on the part of the State of New York held the same views, and new monuments were accordingly erected where the old ones stood.

David Rittenhouse fixed the southwestern corner of the State on a prolongation of the Mason and Dixon line. From that corner the western line was run northward to Lake Erie. By some unaccountable error in the observations the direction of the line from the corner to the Ohio River deflected a fraction of a minute east of north, so that at the river it was something over fifty feet east of its true position. From the river to the Lake the line is almost precisely due north, and the monuments approached with remarkable accuracy to being on a direct line. West Virginia and Ohio, by the error mentioned, have territory that rightfully belongs to Pennsylvania, but, the monuments having been placed on the ground by legal authority, the error in the line could not be corrected. I cite these facts to show that the monuments placed upon the ground must be adhered to.

Harrison Souder.—I was once called in to locate the boundary line between two mining claims in the Southwest. The corner monument was a barrel full of stones,—a remarkably convenient corner when either company desired some of the other's land. The instructions for locating corners and lines, issued to the United States deputy mineral surveyors, give excellent results.

Mr. Nichols.—In the United States surveys of public lands, the main lines were run with a compass and magnetic needle, but after the invention of the Burt solar compass the principal meridians and township boundaries were run with that instrument. In recent years the use of the transit has been permitted, but the surveyor must establish his north and south lines by polar observation, and in running east and west lines he must take back sights and fore sights, allowing at every mile for the curvature of the earth at that parallel of latitude. After the establishment of a principal meridian the country is blocked out in checks from thirty-six to forty-two miles east and west, and twenty-four to thirty miles north and south. The general method in this country has been to establish the principal meridian for a considerable distance, then back up, and at the southern extremity run either east or west and establish the south boundary of a check, thence north and back east or west again to the principal meridian. They are allowed about four chain lengths for distance, and about one chain for deflection with the proper corner originally established. If more than this variation is discovered, the work must be re-run. The six sections along the north side of each township are generally fractional, being either over or under, as the case may be. These errors are confined within certain limits, and if they are exceeded the work must be done again. After the townships are blocked out the same procedure is taken to divide it into sections, which are one-mile square. In Arkansas, where I have had some considerable experience in retracing original government lines, and where the trees had not been cut off to any extent, I found it very easy to trace the lines and establish the corners, but I found that the field notes and the actual distance varied considerably, in some cases over a quarter of a mile from the actual measurement, on what was noted as one mile.

MR. LEHMAN.—I have been told that a great deal of the chaining was done on horseback.

THE PRESIDENT.—To show how large an error in land surveys may arise I will mention that after the State of New York had carried some of the secondary points of the coast survey over the State, for the purpose of furnishing better and more reliable points for future surveys and for testing the surveys already made, it appeared that towns in the central part of the State were from eight to ten miles away from the location given on the standard maps. It might seem that the points raised in Mr. Lehman's paper were such as might be considered more properly belonging to the lawyer than to the engineer; but I have felt that we can not have a very long experience as engineers, civil or otherwise, without being brought face to face with difficulties which involve points in common law, and that generally the engineer must obtain a better understanding of some of the fundamental principles of the common law than he usually has. My experience has been that the counsel of a corporation or municipality needs very seriously the aid of an engineer in properly drawing up his contracts. Very often contracts and agreements are drawn up in such a way that you would imagine there was only one party to the agreement, and that, of course, is not equitable, and the engineer should not permit such a state of affairs to exist. I have recently been brought into contact with the fact that there is a considerable literature on this subject of engineering jurisprudence, and in the library on the sixth floor of the Public Buildings I found some works by American authors which seemed to be very carefully compiled; two of the works are quite elaborate.

For the advantage of those who may desire to consult literature of that kind, I will read the titles of the books I refer to :

"The Law of Building, Engineering, and Ship-building Contracts, and of the Duties and Liabilities of Engineers, Architects, Surveyors, and Valuers, with Precedents and Reports of Cases." By Alfred A. Hudson. 2 vols. 1895.

"Engineering and Architectural Jurisprudence : A Presentation of the Law of Construction for Engineers, Architects, Contractors, Builders, Public Officers, and Attorneys at Law." By John Cassan Wait. 1898.

"The Law Relating to Building Leases and Building Contracts." By Alfred Emden. 1895.

"The Law of Building and Buildings : Especially referring to Building Contracts, etc., containing also various Forms useful in Building Operations and a Digest of the Leading Decisions on Building Contracts in the United States." 1894.

MR. LEHMAN.—I have had recently a little correspondence with Mr. John C. Wait, of New York, the author of the work on "Engineering and Architectural Jurisprudence." It is quite a large book, consisting of one thousand pages. Looking over the index, I find he does not touch at all on questions of land-surveying jurisprudence, but discusses mainly the jurisprudence of engineering and architecture. I asked him why he appeared to ignore our part of the subject, and he said he was aware that this work does not include matter on that subject, but that he had a great deal of data and was preparing a manuscript for a work especially on this question, and that he now requests any one who could help him to assist him with any information based on experience.

JAMES CHRISTIE.—Aside from the technical questions, the subject of professional ethics is involved. It is a delicate subject, and, as frequently shown, one on which there is no defined status, as relating to the engineering profession. If a contract is made between two parties for a fixed sum, the amount of work to be performed and its character should have been more strictly defined than appeared in this case. Very often the employer has but a vague conception of what he desires. He may need but a topographical map of his property. If he desires corners and boundaries to be relocated and verified, or an examination more of the nature of a geological survey, the amount of time and labor expended might be vastly extended. It should be the duty of the engineer to specify exactly what he proposes to do, just as if it was an ordinary commercial transaction. Then there is less probability of mutual misunderstanding when the work is completed.

J. KAY LITTLE.—I should like to know the exact question involved here,—whether it was to make a survey to find the contents or to mark the corners without marking the lines. You may make a survey for contents only, or to run lines between those corners.

MR. LEHMAN.—Primarily the object of the survey was this : encroachments had been made,—the country is full of timber, more or less,—and what are called wood-jobs were going on all around the boundaries, and in some cases the company, knowing this, believed its lands had been encroached on, and wanted first to find out where their lines really were, being well aware that its "wood boss" did not know. It was in regard to cutting the vista around the boundary that the main contention was made. In addition to the outside lines, knowledge of the relative positions of the lakes and the height of the mountains and the acreage of the whole property was desired.

MR. LITTLE.—The cutting through would not have fixed the lines?

MR. LEHMAN.—Not precisely, but there would have been no difficulty in marking their approximate position, with the advantage that in case any operation took place, wood-chopping or otherwise, the location of the company's line would be known.

MR. RICHARDS.—How were those lines established? Was there any meeting with the parties owning the adjoining property?

MR. LEHMAN.—No. During the progress of the work there was no contact at all with outside land-owners, and in many cases the corners were easily found and marked. In some few cases they were stumps of old trees, which had been cut down before the last survey had been made. We discovered about seventy-five per cent. of the corners, but there were only about fifty per cent. that had not been tampered with.

MR. CHRISTIE.—To what extent is the stadia system of measurement used now? Is it found to be reasonably correct?

MR. LEHMAN.—I have found that very few engineers have become converts to the stadia method of measuring. They do not appear to have much confidence in it. Those who have been compelled to take it up use it for some kinds of work in preference to any other method. In work for preliminary railway surveys it is unquestionably the most economical. I have myself run many hundreds of miles with it, and profiled and estimated the work on this basis. For land surveys of small area and on level ground it should not be used in preference to the chain, because the chain is then most reliable. For large surveys over rough ground it is unquestionably better than poor chaining, and when it is difficult to get experienced chain men. One method is always to measure the vertical angle of the distances measured and reduce to horizontal distances, and in that way more accurate results can be had than with a chain. In answer to the question, I must admit that few engineers know the advantages of the stadia method for railway surveys. A corps consisting of five men can do the work of a corps of eleven, twelve, or even thirteen men. In the hands of the expert, the method would need the assistance only of a good rod man and one or two others. Of course, when it comes to absolutely accurate work, such as railway location and running in curves, it is unavailable.

L. F. RONDINELLA.—In answer to Mr. Christie's question as to the reliability of measurements made by the stadia method, I believe that with good instruments and careful readings very accurate results can be obtained, except in unusual conditions of the atmosphere; and while the measurement of distances by the stadia is more rapid than chaining under all circumstances, it is vastly superior over rough ground and in taking topography data. In making a topographic survey of the eastern end of Long Island to Fort Pond Bay a few years ago, I used the stadia method with very satisfactory results. The surface of the country there is peculiarly uneven, the elevations varying suddenly from the sea level around the coast and the shores of five lakes to bluffs 85 feet and hilltops 135 feet high, with underbrush and swamps in the hollows. A north and south line three miles long was first laid out across the widest part, near the center of the property, with special stakes at every eighth of a mile point. From these points lines were run east and west to the boundaries of the property, and with instrument stations on every second line; the topography readings were taken on one transit from two stadia-rods worked around in a semicircle from north to south, one rod taking points within about 500 feet of the instrument, and the other taking points beyond up to about 800 feet from the instrument. As soon as the readings were taken and recorded from one rod it was carried to a new position, while the instrument was turned on the other rod, and in this way the ground was covered very rapidly, the topography of a quarter of a square mile or more being taken on each good day. The notes were afterward plotted to a scale of 200 feet to 1 inch, with 5-foot contours, and the closure errors of the different circuits were very small.*

MR. LEHMAN.—Some years ago an industrial corporation in Pennsylvania had purchased an iron-ore property containing some thousands of acres of land. The company desiring a topographic survey of the property, their engineer corps worked on the survey of the lands for about five months. I saw the map of the surveys subsequently, and was told that the work had cost several thousand dollars. My attention had been called to this map by our State geologist, and I was asked to go over the work and do identically what had been done by the surveying corps. A test of the merits of the work was wanted. I did with three men in six weeks what had taken a full corps five months to do, and where their work cost thousands, mine cost hundreds. The results of their work and mine were practically the same, as was proved by a careful comparison of our maps. Not one of the men of the iron company's corps appeared to know of the advantages of the stadia methods, else why would they have resorted to the cumbersome and expensive methods of chain, transit, and level, requiring the use of fourteen or fifteen men? The chief engineer of the company was not aware that the work could have been accomplished with less cost and time.

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* In support of the above statement, Prof. Rondinella presented the following figures at the meeting of May 21, 1898:

		CLOSURE ERRORS.	
Length of Circuit.	*Number of Stations.*	*Azimuth.*	*Elevation.*
13,943 feet.	30	0°— 0′	0.1 feet.
17,150 "	34	1°—15′	1.2 "
13,625 "	25	0°— 4′	4.9 "
16,438 "	20	1°— 0′	5.6 "

RECENT DEVELOPMENTS IN THE APPLICATIONS OF STORAGE BATTERIES.

JOSEPH APPLETON.

Read June 4, 1898.

In the history of the electrical industry in the United States there is probably no branch which has shown such a rapid growth as in the case of the storage battery during the last three years. The following figures show the enormous increase during this time; they have been carefully compiled and represent the actual weight of storage-battery plates installed. The weight is that of plates alone, and does not include containing-cells, acid, etc.

1894,	349,000 lbs.
1895,	1,112,800 "
1896,	2,315,300 "
1897,	3,607,300 "

or ten times the business of 1894.

It will be readily seen that, in order to create such a growing demand, new applications must be constantly developed, and it is to some of the most important and interesting of these that your attention is invited to-night.

Only a few years ago, if an electrical engineer recommended the use of a storage battery, he was immediately put down as a "crank," and one to whom it would be unwise to intrust any important engineering problem; but now it is the exception to find an engineer who will not consider the use of a storage battery as an auxiliary in all cases of generation and transmission of electrical energy.

One of the most important of recent applications of storage batteries is in connection with the development of "water-powers" for the generation, transmission, and distribution of electrical energy for power, lighting, and manufacturing purposes. It is well known that the demand for electrical energy in any district, whether in the form of power or light, is a variable one. At certain hours of the day the load is small, while at others, and usually for short periods, the load is great. This variation is always more marked in the winter months than in the summer. Quite recently I was discussing the use of batteries for loads of this nature with the engineers of one of the largest electric light and power companies in the country, and they made the statement that fifty per cent. of their investment, in generating plant and underground copper, was only used for *one hundred and fifty-four hours* during the *year*. No doubt, at first, this seems an astonishing statement to many of you; but I will venture to say that it is the condition which exists in many, if not the majority, of such plants in operation to-day.

To operate such a load from water-power means that only a small portion of the total power can be utilized. In the West, where there are enormous water-powers available, this is especially the case, for it is impossible to dam up the water, even where feasible, on account of the irrigation rights, which have a first claim on the water, and which require a constant flow. By using a storage battery as an auxiliary to the generating machinery a much more regular load can be kept on same, as, no matter whether the fluctuations are rapid, as in a railway or power load, or occur at stated periods in twenty-four hours, as in a lighting load, the battery will store up energy when the demand is below the average and discharge when it is above the average, keeping the load on generators and water-wheel fairly constant. Furthermore, it is only necessary to install machinery for the average load, instead of the maximum, thereby saving a large amount in investment, as in plants of this description the average load is frequently but thirty or forty per cent. of the maximum, and, while the maximum only occurs for a very short period, sufficient generating machinery has to be provided to meet it. When electrical energy is furnished for manufacturing purposes, in addition to the fluctuating character of the load there remains the fact that the majority of mills run only ten or twelve hours a day.

Take, for example, the Niagara Falls power. There electrical energy is sold for so much per H. P. per annum ($40, more or less, according to the amount taken), the power being available for twenty-four hours per day. Now, if a manufacturer requires it for only ten hours per day, it costs him 2.4 times as much as if he were able to use it twenty-four hours per day, but, by using a storage battery in connection with the Niagara Falls power, he can get along with one-half the amount or less. For example: A man requires 100 H. P. for ten hours per day; he really pays for 100 H. P. for twenty-four hours, or 2400 H. P. hours, while he can use only 1000 H. P. hours, and his average is sure to be less, for, while he has to pay for the maximum amount, he is never able to use this amount constantly. With a storage battery capable of storing 50 H. P. for ten hours he need only pay for one-half the average amount he uses, as the battery will furnish the remaining half, together with the fluctuations above the average. The battery is charged during the fourteen hours when he is not using the power. Experience shows that this system enables a manufacturer to contract for about one-third the amount of power he would otherwise have to take; and while it is not intended to enter into details of cost of batteries in this paper, I would like to say here that such an investment in a storage-battery plant very soon pays for itself.

The Buffalo Street Railroad Company have recently installed a very interesting battery plant, on these lines. They operate practically all the cars within the city limits, and have a steam plant capable of delivering 7000 electrical H. P. and 2000 H. P. in two-phase rotary converters, supplied with high tension alternating current from the Niagara Falls plant. Their storage-battery plant has a capacity of 1200 H. P. for one hour, and the cells are made large enough so that plates can be added to bring up the capacity to 2000 H. P. for one hour. The battery operates in connection with a "booster," which compounds it to any desired extent.

The slide illustrates the load-curve for May 13th, and indicates clearly the effect of the battery on the system. The aim, of course, is to keep the rotary converters as fully loaded as possible, in order to get the greatest advantage from the Niagara Falls power.

Before installing the battery they were only able to shut down their steam plant from 11.30 P. M. until 5 A. M. During this time the rotary converters carried the load, which averaged only about 600 H.P.; now they shut down the steam plant from 7 P. M. until 7 A. M. and eighteen hours on Sunday. During the day they run only one 800 K. W. generator by steam, instead of 1400 or 1600 K. W., and that at absolutely constant load.

The battery takes care of all the fluctuations and peaks. The rapid fluctuations can not be seen on the slide, as the curve was plotted from observations taken every fifteen minutes, which will not show the rapid variations. It is alternately charging and discharging during the day-time, as the load varies, but receives its full charge at night from the converters. It is apparent how large a proportion of the load has been transferred from the steam plant to the rotary converters, by means of the battery, thereby greatly increasing the average power obtained from them.

It will be noticed at 2 A. M., when the battery is practically fully charged, two of the four rotary converters are shut down; but when the additional plates are added to the battery, bringing it up to its full capacity,—this will probably be done before the heavy winter's load comes on,—the rotary converters could be run at full load all through the twenty-four hours, in which case the company would be actually using every bit of the Niagara Falls power they contract for.

The battery plant has not been in operation long enough to ascertain the actual saving per annum, in dollars and cents, that has been effected; but, so far, the coal consumption has been reduced twenty-five per cent., and their force by five men. In the winter time, with the heavier load, a still better showing will be made.

ELECTRICAL ELEVATORS AND STORAGE BATTERIES.

The modern office building, with its fifteen or twenty stories, together with the demand for quick elevator service, has greatly increased the use of high-speed electric elevators. The nature of the work the elevator has to perform, and the fact that the power required to start it is from two to three times the hoisting power, makes an elevator load an extremely fluctuating one, no matter how carefully their operation is watched.

This slide shows a curve plotted from observations taken every five seconds for twenty minutes, from a plant operating six high-speed "Sprague" elevators. The maximum elevator load recorded during that period was 800 amperes, and at times the load dropped to zero, all the elevators being stationary. This represents a maximum load of 140 H. P., while the average is about 60 H. P.

In this system of operating both elevators and lights from the same dynamos, the elevators are connected directly across the terminals of the battery, and the battery is charged from the dynamos through a constant current-booster, which will allow only a certain predetermined current to pass from the dynamos to the battery and elevator circuits.

In this case the charging current is 250 amperes. The proper charging current is determined by ascertaining the average elevator load and adding to it ten or fifteen per cent. for loss in the battery. When the battery is also used for supplying current at night, after the generating plant has been shut down, the charging current should be increased sufficiently to replace the amount taken out of the battery at night, so that the battery will be fully charged by the end of the day run, and ready to take the night load. Analyzing the load-curve more fully, it is noted that when no elevators are running all the current from the booster goes into the battery; but when the elevators start, this current is diverted from the battery to the elevators and is supplemented by the discharge from the battery. When the battery discharges, of course, its voltage is lower than when charging, and there would be a tendency for a larger current to pass from the dynamo through the booster unless this machine were wound to maintain a constant current. One line shows the current being delivered by the dynamo, and it will be noticed that the extreme variation in the load only amounts to 50 amperes, or 8 H. P., with a variation of 140 H. P. in the elevator circuit. Another line shows the voltage on the dynamo terminals, which varies two volts, or less than two per cent.

In the plant in question only one dynamo is run for both elevators and light, until the peak of the lighting load comes on, when more generators are run in parallel with the first; but at no time are the elevators and lights run from separate dynamos. At night the battery takes care of the lights in the building and thirty or forty trips of one elevator.

To summarize, the advantages of this system are:

Smaller generating plant necessary.

Only one unit need be run, instead of two, with consequent saving in labor.

Greater economy of operation, due to plant being run at a constant and efficient load instead of a varying one.

Smaller depreciation on plant, due to entire absence of heavy loads being suddenly thrown on same.

Greater reliability on account of battery being ready to take entire load in case of emergency.

The general adoption of electrical elevators has been retarded by the fact that it was considered necessary to operate them from a separate dynamo from that which was supplying the lights, or, on the other hand, to sacrifice the steadiness of the lamps if they were both run from the same dynamo; but with this system this trouble is entirely overcome, and there is now no reason to complicate the electric plant in any building by adding hydraulic machinery. This system is applicable in exactly the same way to large buildings operating electric elevators from electric-lighting mains. Frequently electric-lighting companies will refuse to connect electric elevators to their system, especially at a distance from their stations, on account of the disturbing effect on their pressure; but with this system only a constant load, equal to the average demand of the elevators, is taken from the system, the battery taking care of all fluctuations.

The storage-battery plant recently installed for the Chicago Edison Company is interesting chiefly on account of its magnitude.

For years it has been customary to refer to European practice for examples of storage-battery applications, but lately this has been unnecessary, as we have many plants here equal to anything on the other side.

Now we can point with satisfaction to the installation in Chicago, which is fifty per cent. larger than any battery in the world.

I will briefly describe it, as it illustrates forcibly the remarkable development of the storage battery, and shows conclusively that the battery of to-day is not an experiment or toy, but a piece of apparatus constructed on proper mechanical, electrical, and chemical lines, and one which is as much of a factor in the generation and distribution of electrical energy as boiler, engine, and dynamo.

The Chicago Edison Company operates a very extensive three-wire Edison system, their maximum load last winter, in the down-town section alone, being 44,000 amperes, or 8000 electric H. P. Should the present growth of business continue, the winter maximum for 1898 will be in the neighborhood of 55,000 amperes, or nearly 10,000 electric H. P. They have provided for the increase by the storage-battery plant, which is capable of delivering 12,000 amperes, or 2000 electric H. P., for one hour.

The situation is a favorable one for battery installation, as the current is generated at one large station, situated 3500 feet away from the center of distribution in the city, the two places being connected by a trunk-line containing 66,000,000 circular mils of copper. It is installed at the center of distribution, being located in the basement of the Edison Building, on Adams Street, the site of the original plant. This is a very favorable point for the battery, as an additional investment in both generating machinery and trunk-line is saved. It consists of 166 cells, arranged 83 on each side of the three-wire system. Each cell contains 87 plates, 15½ by 32 inches. The containing-cell, or tank, is constructed of two-inch ash, lined with five-pound sheet lead. The dimensions of each cell are 1 foot 9½ inches wide, 6 feet 8 inches long, and 4 feet high. The weight of each cell is 6200 pounds. The total weight of the battery, exclusive of copper conductors, is 1,029,200 pounds. The connections between the battery and the Edison system are made of copper conductors, 6 by 1 inch, giving a sectional area of 6 square inches.

The principal use of this battery is to carry the peak of the load, which occurs between 5 and 6 o'clock P.M. in winter and to a smaller extent and somewhat later in summer, although it will be used during the remainder of the day to equalize the load on the generators and maintain a steady pressure on the system.

ELECTRIC VEHICLES.

The question of electric vehicles is, to the general public, probably the most interesting among recent applications of electricity, and the field it opens up for storage batteries is almost beyond limitation. The last few years have seen the electric motor replace horses in our street cars, and those who have followed the conception and growth of the electric vehicle prophesy the same revolution in the carriages, cabs, wagons, etc., in our cities. Of course, to lovers of horseflesh this change will not appeal, for the substitution of a controller for a well-bred animal would deprive them of the principal pleasure of locomotion. There certainly can not be the same sympathy and affection between the owner and the electric motor as there is between him and an intelligent animal; but for commercial uses, where dollars and cents, and not sympathy, count, the case is different, and there are many reasons why the electric vehicle should supersede our present methods.

The cost of accomplishing by electric vehicles the work now done by horses would be probably one half, when their adoption has become to any extent general, thus enabling the work of recharging the batteries to be organized on a proper scale.

There is an immense advantage from a sanitary point of view. Think of the hygienic measures necessary to care for the refuse of 100,000 horses, both in the stables and on the streets. This is about the number of horses in Philadelphia. Again, if the wear and tear of these 100,000 horses traveling over the streets and roads were done away with, how much simpler the problem of good roads would be. The electric vehicle possesses so many advantages over those propelled by oil or gas motors that, except for special conditions, where extremely long distances have to be covered without charging facilities, there seems to be little, if any, doubt that the former type will be the one to fill the field.

Briefly stated, the advantages of the electric vehicle over oil or gas motors are as follows:

Safety.—A storage battery will not explode, nor is it inflammable, like gasolene or kerosene.

Ease of Handling and Control.—An electric motor, with its controller, is certainly the ideal method of control, and is distinctly not in the same class with the levers and valves necessary to operate an engine.

Absence of Noise and Vibration.—Here, again, the electric motor is the ideal motor for the purpose, having a smooth rotary motion, instead of a reciprocating action, with its noise and vibration.

Absence of Heat and Smell.—An oil or gas motor must, of necessity, be accompanied by considerable heat, and usually requires a water-jacketed cylinder. From the exhaust there is an objectionable odor, due to the unconsumed gases; but with the electric motor neither of these objectionable features exists.

Cost of Operation.—There is no doubt, from independent tests made, that a vehicle can be propelled electrically with less consumption of energy than any oil or gas motor.

There are many other points which might be touched upon, but these will suffice. For city use, the question of large mileage capacity does not handicap the electric vehicle in favor of the oil or gas motor, as the supply of electricity can be renewed as desired by recharging the batteries. This part of the problem we will consider later.

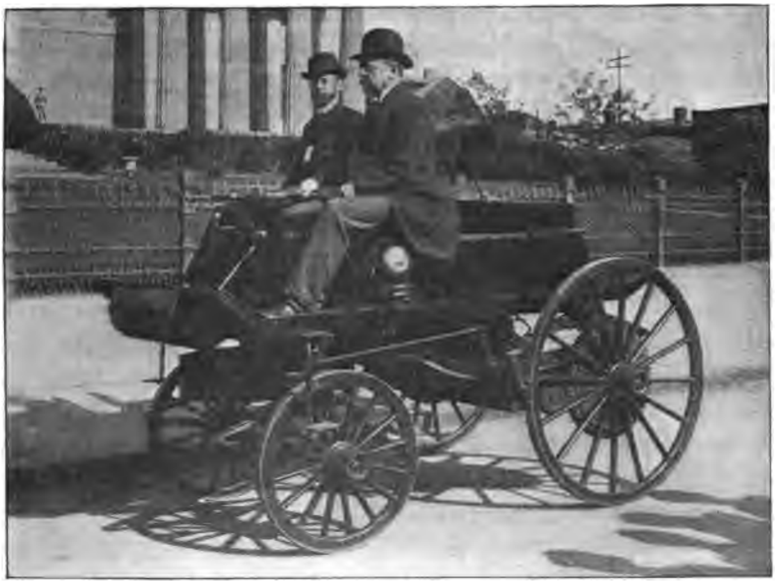
The electric vehicle of to-day is the result of much arduous and expensive experimental work, and this Club has the honor of containing among its members two gentlemen who have been foremost in the development of the electric vehicle in this country.

Messrs. Morris and Salom first took up the question in 1894, at which time very little had been done, either in this country or abroad, and the numerous problems of motors, gearing, wheels, tires, bearings, running gear, etc., had to be investigated and solved without the light of previous experience. The first vehicle they designed without regard to appearance, their object being to ascertain the best type for self-propulsion through all sorts of streets, considering, especially, the features of weight, size, mileage, and distribution of machinery. The cut shows this vehicle. It weighs 4250 pounds without passengers. Its mileage capacity, on one charge, was 50 to 100 miles, according to speed and grade. The battery weighed 1600 pounds. The motor was 3 H. P. nom., but capable of developing 9 H. P. for a short period, weighing 300 pounds. The maximum speed attained was 15 miles. It was most successful, and traveled hundreds of miles without accident.

The data obtained from this proved that on good pavements a vehicle weighing, with passengers, 5000 pounds could propel itself at a speed of 10 miles an hour, with an expenditure of energy not over $3\frac{1}{2}$ H. P., or $\frac{7}{10}$ H. P. per 1000 pounds.

These gentlemen next designed and constructed the vehicle known as the Electrobat, No. 2, which won the gold medal in the "Times-Herald" motor-cycle contest, held at Chicago in November, 1895. This weighed only 1700 pounds with batteries, which was a great reduction in weight. The equipment consisted of two motors, each $1\frac{1}{2}$ H. P., attached to the front axle, the pinions on the armature shaft gearing directly into the driving gears attached to the front wheels. The steering is accomplished by the hind wheels. The battery consists of 44 cells, having a capacity of 50 ampere-hours, each cell weighing 13 pounds. The controller is conveniently located at the front seat and gives three speeds ahead and one backward, obtained by various groupings of the cells and motors. The maximum mileage on one charge was 25 miles, at 12 miles per hour; the maximum speed, 20 miles per hour. In the "Times-Herald" race this vehicle met in competition every description of motor vehicle, and the fact of its being awarded the gold medal is sufficient proof of its superiority and merit.

Messrs. Morris and Salom then proceeded to design electric vehicles for different classes of work,—*e. g.*, hansom cabs, coupés, and delivery wagons, etc. The next step forward was the formation of the Electric Carriage and Wagon Company, to operate vehicles in actual service in New York City. This slide shows the first stables, with twelve cabs on one side of the building, and the battery-rack, upon which the batteries were placed for charging, on the other side.



MOTOR CARRIAGE. DESIGNED BY MESSRS. MORRIS AND SALOM.

After more than a year's successful experience with these cabs it was decided to extend the scope of operation, and next month fifty more cabs and fifty broughams will be in operation in New York City in ordinary hacking service. Eventually, more stables will be opened in New York City, and also in other cities.

The new vehicle will be of similar design to those illustrated, but will contain certain minor improvements and additions, which experience has found to be advantageous. For example, the backward speed is obtained by a separate reversing switch, operated by the foot instead of by the controller, as it was found the driver would use the reverse position to stop his vehicle, instead of using the brake, thereby putting more strain on motor and battery.

An emergency switch is provided, which the driver operates by giving a spring a kick with the heel and releasing a little strip of copper from two contact blocks. This switch is also used if the driver wants to leave his vehicle on the street; he puts the copper link, or little strip, in his pocket and renders the vehicle inoperative. These new cabs show a marked improvement over the previous ones in the question of efficiency. At a speed of 12 miles per hour they take an average of less than 2½ H. P., and will have about 40 miles' capacity. When going up an eight per cent. grade, which is rarely met with in city use, they can make 6 miles an hour with 7 H. P. This is far better than has ever been done before. The wheels are fitted with pneumatic tires of 5 inches' diameter, inflated to about 120 pounds.

A vast amount of skill and care has been expended in laying out the new stables, and the arrangements for handling the vehicles and batteries will be most complete. It is the first plant of this kind in the world, and I had hoped to have photographs of the interior, but things are hardly finished enough to allow this. I have, however, a rough sketch, which will give an idea of the arrangements.

The building is located on Broadway, between Fifty-second and Fifty-third Streets, and runs through to Seventh Avenue. Accommodation is provided for 100 vehicles, with two sets of batteries for each. The batteries will be charged from the Edison three-wire system, each set of batteries containing forty-eight cells, which is the proper number for charging from the Edison system, without wasting energy in rheostats, etc. Eight rows of charging tables are arranged lengthwise down the room, upon which the batteries will be placed for charging. The act of placing the battery on the table makes contact with it and the charging circuit by an ingenious device. Four different charging voltages are provided by means of boosters, and when a battery comes in from service it is connected to the lowest of the 'busses. This is done by a four-point switch on the switchboard, which connects the battery to any of the 'busses. Besides the switch there is in circuit with each battery a current indicator, which automatically lights up a colored incandescent lamp when the charging current has fallen below the limit.

Let us follow a set of batteries through the charging operation. It is first placed on the charging table and connected to the lower pressure, which will allow the proper charging current to pass into the battery. As this charges, its voltage rises and the current decreases. When it drops to the point at which the indicator is set, the lamp is lighted, and the switchboard operator knows that it is time to switch the battery on the higher 'bus. This being done, the current is increased by the higher voltage, and the signal-lamp is cut out until the current drops again, and so the operation proceeds. If it is desired to charge the battery quickly, it is only necessary to connect it at once to one of the higher 'busses.

This system of charging is the most efficient that could be adopted, for if the battery is switched on the full voltage it charges very rapidly at first, and the current falls to almost zero when the battery is fully charged. There is no objection to charging in the latter way, as far as the battery is concerned, but in a large plant like this it would not be so convenient or economical as if the charging current were regulated.

The apparatus for handling the batteries—taking them out of the vehicle and placing them on the charging tables—is very ingenious, and enables one man to handle the entire outfit. An overhead traveler runs the entire length of the charging tables, and from this traveler are suspended eight lifting clutches, or arms,—one for each row of tables. In front of the charging tables there is a traveling conveyer, which will carry any battery deposited upon it in a direction at right angles to the battery tables. This is used for bringing the batteries to a position opposite the vehicles when they are brought in for a new battery. In front of the conveyers are two hydraulic floating platforms, on which the vehicles rest. The traveler, lifting clutches, conveyer, and hydraulic platforms are all controlled by one man from a small platform suspended underneath the traveler.

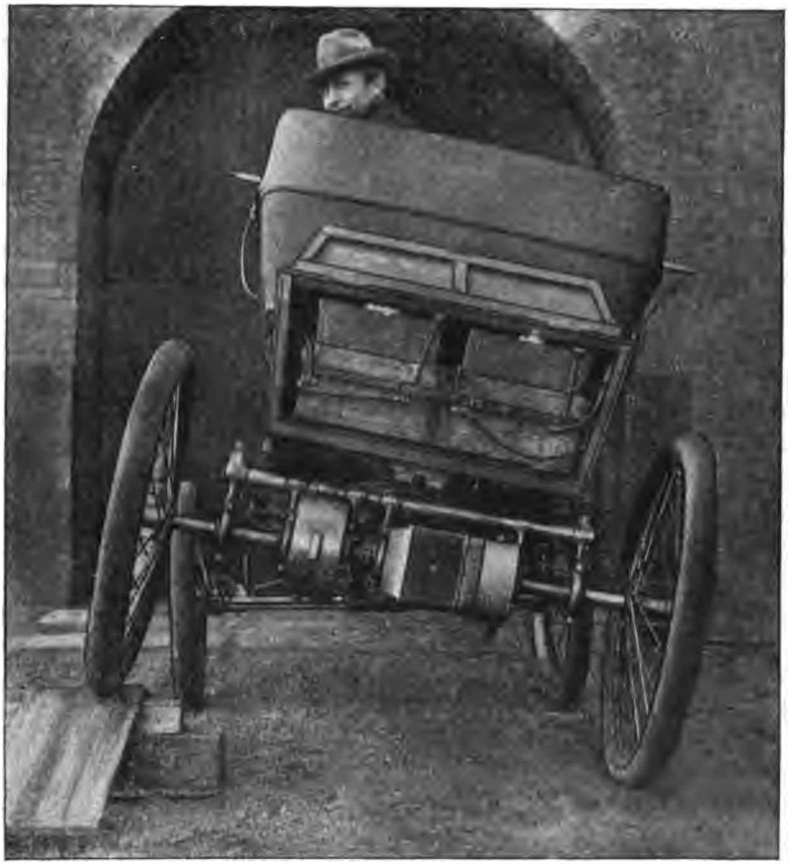
The *modus operandi* is as follows: A vehicle comes in to change its battery; it backs on to one of the platforms, a clearance of fourteen inches in width being allowed for the driver to steer in. The operator on the platform centers the platform immediately opposite an empty section of the conveyer. A grappler runs out and withdraws the empty battery on to the conveyer. The conveyer is then moved one section, so that a full battery is placed opposite the vehicle, the grappler pushing it into position in the vehicle. The contacts are made, in the vehicle, by springs rubbing against the side of the box. The empty battery is now carried away by one of the lifting clutches and deposited on the charging table, a full one being brought back to the conveyer for the next vehicle which comes in. The entire operation of changing will take less than two minutes, a shorter time than is usually occupied in changing horses, and with much less labor. In addition to this apparatus, there are two electric elevators for raising the vehicles to the storage floor when they come in at night and have been washed.

There is a complete testing room, for making tests of motors, batteries, gearing, etc., while on the vehicle, so that the proper standard of efficiency is maintained; also, machine shop, painting shop, etc.,—in fact, nothing has been omitted which would render the plant complete.

In addition to these charging arrangements, the Edison Company will provide charging plugs in the street, all over the city, so that, if necessary, a cab can pull up alongside a charging plug and fill up. These charging plugs will be somewhat similar in appearance to the ordinary street hydrant.

The Pope Manufacturing Company, the well-known makers of the Columbia bicycle, have taken up the manufacture of electric vehicles. Their vast manufacturing experience and exceptional facilities for making tubular frames, wire wheels, and pneumatic tires render this company specially fitted for turning out the highest-class of vehicles, both from an engineering and commercial standpoint. Its attention has been given to vehicles for private use, rather than public operation from a central stable.

The cut shows one of the designs this company offers, which is a beautiful specimen of workmanship. Wire wheels with three-inch pneumatic tires are used. In the single-seated vehicle there is one motor and a balance-gear on the axle, to allow of one wheel turning more rapidly than the other going round corners. In the two-seated vehicle there are two motors instead of the balance-gear. The same course has been pursued as with the bicycles,—viz., examining and testing every part of the apparatus, to avoid accidents from flaws in material or workmanship.



Obstruction Test of Motor-Carriage.

Obstruction tests are shown, which are given every carriage and each set of batteries before sending out. The obstruction is ten inches high and the carriage is run over it at a speed of about five miles an hour. The bump is sufficient to lift the occupant about four inches off the seat. The mileage of the single-seated carriages, in New York City streets, is about thirty miles. Over country roads, in the vicinity of Hartford, Conn., where there are many hills and roads having poor surface, a mileage of twenty-eight miles has frequently been obtained. Over these roads the average speed, including all stops and slow-ups, is 9¾ miles per hour. The average consumption of energy, on good roads, including all zero readings when coasting, is about 1760 watts, or 2⅜ electric H. P.

The fact that the carriages are used by the general public, and are not operated or controlled under skilled supervision, as in the case of cabs, has made it necessary to work out a system for recharging which the purchaser can carry out without trouble. Forty-four cells are used on each vehicle, so that an ordinary 110-volt circuit can be used for charging. The batteries are charged in position, a suitable plug-connection being provided. In each vehicle is arranged, in the battery-circuit under the seat, a specially designed Thomson recording watt-meter, which, when the battery is charging, runs backward, and at a certain slower speed than when the batteries are discharging and operating the carriage. Instructions are given to continue the charging current until the watt-meter returns to the full position. This absolutely insures that a certain percentage of increase of current over what has been taken out has been put back into the batteries. The batteries are fully charged in from three to three and one-half hours. When first plugged in the current starts at forty to fifty amperes, gradually decreasing to about ten amperes as the counter electro-motive force of the battery builds up.

The Fischer Electric Equipment Company, of Chicago, is preparing to operate in that city vehicles of all descriptions. I have here some illustrations of the designs. The lines it proposes to work on are to furnish the entire electrical equipment to carriage-builders, using the ordinary design of carriage, with as little alteration as possible. Experience leads it to recommend two motors, thus doing away with balance-gear, and to the use of wood wheels in preference to wire wheels, and solid rubber tires in preference to pneumatic ones. It is claimed that pneumatic tires take twenty to fifty per cent. more power for the same load than solid tires, besides depreciating far more rapidly. It is proposed to do the charging with the battery in position, assuming that the public vehicles will have ample time during the day to charge from the street-plug and to adopt a prepayment system for this charging, the man putting into the switching apparatus on the charging plug a certain amount of money and getting in return a definite quantity of electrical energy.

The Riker Electric Motor Company is also building electric vehicles. Those illustrated have been in service for some considerable time, the Victoria having made 3000 miles and the four-passenger trap 1200 miles. The electric delivery wagon shown is being operated by Altman & Co., in New York City.

The electric-motor vehicle must of necessity contain mechanical and electric apparatus which, in order to be maintained in proper working order and the highest state of efficiency, must have intelligent and systematic inspection. If this care and attention are given periodically, there is no doubt of the reliability and usefulness of these vehicles. It can hardly be expected that the general public will be able to give this skilled attention, and comparatively few users of such vehicles would have a mechanic in their employ who would be competent; therefore the lines upon which the business will be developed will probably be the construction of charging stations in suitable locations in the city, where the vehicles will be kept when not in use and where they will receive such attention as is necessary.

There is no doubt that the electric vehicle has come to stay. Whether future developments will lead to a different design it is impossible to say. The first railway coaches were constructed after the design of the old road coaches, but the design became modified in order to produce a vehicle which was best suited to the new method of locomotion. So it may be with the electric vehicle. The design may gradually change until we have a type of motor-vehicle entirely different from the horse-carriage.

Another direction in which improvement is looked for, but which, I venture to say, is a long way off, is the reduction in weight of the battery. So far nothing but the lead battery has been found practicable, in spite of the large amount of time and energy which has been expended in the direction of employing other and lighter metals; but some day these hopes may be realized.

A recent application of storage batteries, which illustrates how wide and varied is the field, is their adoption in telephone exchanges.

Modern telephone practice centralizes the batteries on the system, placing them in the exchange, instead of at the subscriber's instrument. The advantages of this system can be readily understood. The batteries are under constant supervision of experienced men, and a few large cells will replace many thousands of cells of primary batteries, which were originally scattered over a wide area among the subscribers. The new exchange of the Bell Telephone Company, at Eleventh and Filbert Streets, Philadelphia, contains, probably, the most complete and modern equipment of this kind. It includes a battery of ten cells, which are used to furnish the current required by the subscribers for calling up and talking; a battery of four cells, installed in duplicate, for furnishing the current to operate the disconnected signals and relays; a battery of two cells, to supply current for the operators' transmitters and call-signals. These batteries are charged from motor-generators, which are supplied from the 110-volt lighting circuit in the building. Separate motor-generators are provided for each of the batteries, so that proper voltage is obtained without the loss of energy in rheostats.

This application is quite new, but telephone engineers express the opinion that it is only a question of time when all exchanges will have their batteries centralized in the same way.

DISCUSSION.

CHARLES HEWITT.—I do not suppose any intelligent engineer to-day will deny that the storage battery is a good thing. Yet Mr. Appleton has said that only a few years ago no engineer who recommended a battery would be considered anything else but a crank. Granted that improvements have been made in the plates and cells, the battery is the same to-day that it was many years ago—I do not know how many, but ten to fifteen possibly. It is pertinent to ask why we Americans have been so slow to appreciate a good thing. Does the fault lie with us, or does it lie with the manufacturers of the battery? European engineers have been using the storage battery very extensively for a number of years in places where they have not been used in this country, except for the last two or three years. I refer to batteries in central stations. It was almost exceptional in Europe to go into any station without finding an auxiliary battery. I ask again why it is we have been so slow, and, in thinking the matter over, it reduces itself to three reasons. In the first place, the manufacturers of storage batteries, in the early days in this country, attempted to use them in places where they were ill adapted, to such an extent and with such failures, electrically and financially, that engineers were afraid to recommend them. That is one reason why an engineer would be considered a crank. He did not dare recommend it, as it had gone throughout the country as a failure. Another thing has been the excessive litigation which has gone on during a number of years. Happily, this litigation has been settled, and the battery is now upon a legitimate business basis. The third and perhaps most potent reason at the present day is the cost of the battery. Mr. Appleton has said very little about this. He has stated that we can reduce the size of our generating units one-third, and possibly one-half, but the portion we reduce we replace with a battery which costs fifty per cent. more than the generating unit. I may be taken to task for that, but at the same time I believe it is a fair statement. The storage-battery people estimate the output of their battery very liberally, much more than a user finds he can obtain from it for a long run—I mean by the time it is several years old. An engineer from abroad—I think he was an Austrian—made the statement recently that the batteries abroad cost one-third of what they do in this country. I do not know whether that is true; perhaps Mr. Appleton does. At any rate, I know that the batteries sold abroad are much cheaper than those sold in this country per kilowat hour output. When these reasons are properly understood, I believe the statements made as to the engineer being a crank can be appreciated. At the same time there is no litigation of any kind on hand now, and batteries can be used for what they are adapted for, and engineers can use them without being considered cranks.

Henry G. Morris.—It is certainly very satisfactory to those of us who have been pioneers in the introduction of storage batteries to find that the industry has reached the stage of development as indicated by the figures given by Mr. Appleton, even if we have met the usual fate of pioneers.

The subject of the propulsion of vehicles by means of storage batteries is one in which I have been interested with Mr. Salom, and I would ask him to give you some figures relating thereto in supplement of those given by Mr. Appleton.

Pedro G. Salom.—I did not bring any figures with me this evening, and Mr. Appleton has covered the subject so exhaustively in his admirable paper that there is really very little to add. There is one statement of interest, however, that he did not make, and that is that the twelve electric hansoms and one electric brougham in New York have made over 50,000 miles, from April 1, 1897, to the present time (about fourteen months), although we did not get them all into actual service until September, 1897.

These vehicles were the first of their types ever constructed, and there was no data to guide us beyond our experience with the first two vehicles which we constructed, of radically different types. We were compelled to put them into actual public service in competition with vehicles drawn by horses, and without a chance to correct obvious defects or rearrange gearing or parts, and yet, notwithstanding these unfavorable conditions, they have averaged nearly 4000 miles each. This is an extraordinary performance, and must remove whatever doubts may exist as to the practicability of motor vehicles. I do not believe that the first twelve trolley cars can show such a record.

The average mileage of vehicles is very much overestimated.

We have endeavored to gather statistics on this matter, and I think it would be a fair statement to make that few vehicles travel over 15 miles a day. In exceptional cases, such as physicians living in the country, the above average may be materially exceeded. Ordinary delivery wagons, or other vehicles of that nature, do not average over 15 miles, and when compelled to make a greater mileage they must use an additional horse. The vehicles of the Pennsylvania Railroad at their Twenty-third Street Ferry make about 28 miles a day with two horses, 14 miles for each horse, and as that is the cheapest cab service that has ever been given in New York, it is probable they are doing a larger mileage than any other cab service ever before instituted; so that it is a fair criterion on which to base calculations for the future. There is a great deal of foolish criticism in regard to electric vehicles. One point made is that they can not go from here to New York, or a similar distance. If they can go 25 miles per day on one charge, which they are doing now, we think all the requirements of cab service will be thoroughly covered and met; and, if it is necessary, after they have made that mileage, and the system is once generally introduced, there will be other stations where the batteries can be changed or recharged, and that will remove the only valid criticism raised against the introduction of the system which exists, as it will be undoubtedly much cheaper than the present system with horses. The actual amount of power required for a 25-mile drive is about 12 H.-P. hours, and we pay for that about three cents per H. P. per hour, and with a larger station we can probably get it for less. That makes a very small figure for the cost per mile, and especially so when the large rates received for cab service is considered.

E. M. Nichols.—I understand that it costs about thirty-six cents for twelve H.-P. hours?

Mr. Salom.—Yes. That is the amount sufficient to run the machine 25 miles. In other words, you can ride 25 miles for thirty-six cents' worth of power.

Mr. Spalding.—The "common" storage battery first installed at the central office, to replace the two primary cells at each subscriber's instrument used for talking, has completely revolutionized the system of signalling, so that now the subscriber, instead of ringing a bell and operating a magnetic signal at the office, simply takes his telephone off the hook, by which a lamp is lighted in front of the proper operator. The same general system of signalling is also now used on the cords connecting two subscribers' lines, and the condition of the lamps, whether burning or not, indicates to the operator whether the subscribers are still talking or have finished, so that the connection can be taken down.

Two styles of lamps (four-volt and twenty-volt) are used. The higher voltage of the battery, while charging, would materially lessen the life of the four-volt lamp. Two separate batteries are installed, and one is charged while the other is discharged. For the twenty-volt lamps, which are not so delicate, but one battery of ten or eleven cells is employed, with a switch so arranged that ten cells are used for the lamps when the battery is charging and eleven cells when it is discharging. The voltage at the lamp terminals is thus kept practically constant.

This change to automatic signalling throughout is really more important, as far as increased quickness and efficiency of service is concerned, than the actual saving in dollars and cents by the use of storage batteries in place of primary cells for talking.

MR. APPLETON.—I would like to make a reply to Mr. Hewitt's remarks. First, in regard to the difference in cost of batteries in this country and Europe; you must take into consideration the cost of materials and labor, which are big items and which are much higher than in Europe. Mr. Hewitt states that the cost of the batteries in this country is 50 per cent. greater than the generators they would replace. I do not think if that was the case there would be any battery installations made.

MR. HEWITT.—I said a complete steam plant and generators.

MR. APPLETON.—I refer to that too. If the peak which the battery has to carry has a wide base, and of three or four hours' duration, this would make the cost of the battery excessive, and bring the battery up higher than the generator. Take, for example, the case I mentioned in which 50 per cent. of the investment in generating plant and underground mains was only used for 154 hours during the year. For loads of that description the base of the peak is never more than one hour or one hour and a quarter, and at that basis there is no doubt that the storage battery is very much cheaper than the complete steam plant. In regard to the question of costs: in Chicago, where they are figuring on the prepayment system, I believe they will charge 25 per cent. for two kilowatt hours. That is, of course, double or nearly three times what would be the cost to generate in a large station, as described in New York. But where it is supplied as a matter of convenience, they expect to charge the higher price.

MR. HEWITT.—I did not intend for one moment to question the decreased cost of operation of a station by using storage batteries or the battery's facility for accommodating itself to the load. I know only too well, in my experience in this city, the value of such a battery. What I meant was that if we were building a steam plant of the best type, with condensing engines to cost about $85 per H. P., the battery necessary would cost nearly $120 per H. P., which is about the first-cost ratio per kilowat output. As to the operating cost, I do not doubt for one moment but that it would pay in many cases to increase the first cost, in order to reduce the operating expense. I personally think any water-power plant is incomplete without a battery plant. It could never realize the full economy of the water-wheels without this auxiliary; and I also believe that most, if not all, of the railway plants would be benefited by auxiliary batteries in their operating cost. But I still maintain that as to the first cost, output for output, the battery is much more expensive than generating units.

MR. APPLETON.—I think Mr. Hewitt leaves out the question of the time which fixes the size of the battery. I know of several batteries being installed in this country, where the price has been between $60 and $80 per H. P. on the short hour rating.

MR. HEWITT.—I refer to a long time rating.

MR. APPLETON.—It is not, I think, the practice to recommend batteries now, where they will not be advantageous or profitable. There are plenty of opportunities for installing batteries where they will show to advantage.

Francis Schumann.—What is the weight of a complete battery, ready for charging, that will develop 10 H. P. for ten hours?

W. W. Gibbs.—About 100 pounds per H. P. hour. I would like to add, in answer to the questions Mr. Hewitt has asked in reference to the reason storage batteries have made such little progress in this country compared with foreign countries: I think the reason was largely due to the fact of the litigation, which was almost constant from the time the first batteries began to be recognized as a feature of the electric industry of this country. Owing to this litigation, there was no inducement for any effort to effect a development of the secondary battery. The few installations made were defective, and the men who went to the expense of installing even a defective battery did it under a liability to litigation. It was down to 1894 that this litigation continued. While I do not take any special credit, I think it will be recognized by those familiar with the subject that it was through my efforts that the litigation was brought to a determination, and at an enormous expense, and the storage-battery business has not yet recovered from it, and we are not yet in a position to do as Mr. Hewitt intimates could be done—*i. e.*, reduce the price of storage batteries. I want to say, however, that we have got it to a point where we can put it where all other businesses have to be put,—where supply and demand will regulate the price. I venture to say, those who started in the electrical business early thought the rates paid for the dynamos four, five, or six years ago were high,—much higher than they are to-day,—and a much inferior article then was obtained. We were recently asked by a large concern what we would furnish storage batteries for, and we gave them a price on $1,000,000 worth of batteries fifty per cent. less than what we would have made $10,000 worth for. We are endeavoring to educate the country as to the usefulness of storage batteries, and this course can not be adopted without great expense. In 1894, immediately following the determination of this litigation, we made every possible effort to induce people to take up storage batteries, and we spent the first year $40,000 more than we received, although we got a high price, as Mr. Hewitt or anybody else will admit, for the batteries. We are getting down the price, however, and we believe during the coming year we shall be able to reduce the price and give the fraternity a battery which will give entire satisfaction. And it only needs appreciation on the part of people who are producing electric-power plants and giving us generous support by buying what they can advantageously employ to get storage batteries very cheap. The best evidence that they can afford to buy them is that the cities where the greatest amount of storage batteries have been bought are buying more. In Boston they have bought many, in New York and Brooklyn also. It is only those people who find storage batteries beyond their reach that do not know the advantages to be derived from their use. There are many advantages that you can not appreciate until you try them, and these advantages are apparent even at present prices. If there is a general effort to apply them where they can be employed, it will be but a short time only before storage batteries will also be considered cheap.

Mr. Salom.—I think I can answer some of these questions from my experience in New York. We found at our station in New York that the best man to run a motor carriage is the ancient hackman. We started in with young men who had more or less training in practical electric engineering, thinking we were going to improve the personnel of the service by having educated drivers, but we soon discovered that the hackman's business is a profession. They have to know all about the city and how to go everywhere, and it is not every man you pick up who will meet the requirements. As to the matter of running the machine, it is a simple thing. A man can learn to run it in a week, or not at all. The wagon can be driven in places where one would not dare to go with a horse, and with greater speed. You could not find a worse place than Fifth Avenue and Forty-second Street, especially a year ago, when the pavement was torn up. I have seen our drivers go through there and push their wagons wherever there was a chance to get them in, and do it skilfully and without accident. As to accidents, that is a question that can largely be settled by careful inspection. Of course, accidents occur and do occur all the time, but by systematic inspection they can be reduced to a very small number. We started in operation in New York on the 27th of March, and in the month of June, last year, we ran 4600 miles. In that distance we only had six delays or accidents of all kinds. The question of the battery giving out is the most serious one. If a wheel breaks or anything of that kind, you can telephone to the station and get another. But the battery giving out is a more serious problem. We have always insisted, however, that none of the wagons shall be pulled home by a horse. So when the driver has to push his machine home, he does not often get left.

The tire problem has been serious, except so far as punctures are concerned. I think we have not had more than two punctures in 50,000 miles. The other troubles are because the tires were not adapted to the service. The cab service in a city like New York is very severe. The irregularities in pavements, railway tracks, etc., render it, in my judgment, almost impossible to use anything but a pneumatic tire. Of course, it is true that a solid rubber tire requires less power on a smooth pavement than a pneumatic, and a steel tire would require still less than a solid rubber. We require a little over twice as much power to run a vehicle with pneumatic tires than is required on a rail, for the same weight and speed, and the criticism, therefore, that one of the gentlemen made about pneumatic tires is not a just one, unless you take all the factors into consideration. They are very expensive; but we think, now, with the 5-inch tire we have adopted for the weights we have to carry, we expect to get 20,000 miles out of a tire, at which rate they will compare with a steel tire. When you think of a bicycle—only weighing 20 pounds, and 200 pounds with its rider—requiring a 2½-inch tire, it is not unreasonable to expect that vehicles weighing 4000 pounds, and required to go at the same speed, should take a 5-inch tire. It looks awkward at first, but not more so than when pneumatic tires were introduced on the bicycle. And as to the question of taking more power with a pneumatic tire than with a solid tire, the former has advantages which render its use almost indispensable. Experiments have been made which proved conclusively that a pneumatic tire is the proper thing, other things being equal.

THE PRESIDENT.—A thought suggests itself in relation to the operators of the carriages; whether they are called hackmen or not. It is a question as to what class of skill is required to successfully operate an electric carriage. It is a more complex piece of mechanism than a hack or a horse, where, if one or the other breaks down, you can get back in some way. But if an electric vehicle breaks down at a remote distance from a station, a serious difficulty arises.

MR. SCHUMANN.—How many hours will a battery retain its full function when not in use?

MR. APPLETON.—With the present class of battery it would hold for a considerable time. It depends entirely upon the purity of the materials used, so that no local chemical action can take place while it is standing. We let batteries stand two to three months after being fully charged, and there is a loss of only 2 or 3 per cent., which is entirely due to impurities in the materials.

E. A. SCOTT.—I was asked to see a storage battery within a few days, and was assured positively that it had not been charged for thirteen months. It gave full two volts to every cell, and that with a half-dozen lights burning.

ABSTRACT OF THE MINUTES OF THE CLUB.

Regular Meeting, May 7, 1898.—The President in the chair. Sixty-six members and visitors present. A. E. Lehman read a paper entitled "A Case of Jurisprudence in Land Surveying." The subject was discussed by Messrs. Nichols, Richards, Franklin, Africa, Schermerhorn, Souder, Christie, Little, and Rondinella.

A memorial notice of the late Rudolph Boericke was read and ordered to be spread upon the minutes.

Regular Meeting, May 21, 1898.—The President in the chair. Seventy-two members and visitors present. E. D. Meier (non-member) read a paper upon the "Diesel Motor." The subject was discussed by Messrs. Schumann, Landis, Falkenau, Hering, Lewis, Ledoux, Christie, Smith, Coffey, and Schermerhorn.

Charles Piez exhibited and described views of a moving stairway and an air-conveyor.

L. F. Rondinella gave some figures to show the accuracy of results obtained by the use of stadia.

Business Meeting, June 4, 1898.—The President in the chair. Eighty-nine members and visitors present. Joseph Appleton read a paper entitled "Recent Developments in the Application of Storage Batteries." The subject was discussed by Messrs. Hering, Schermerhorn, Hewitt, Morris, Salom, Spalding, Schumann, Gibbs, Scott, Leffmann, and Eglin.

A Conversational Meeting was held on May 14, 1898. Mr. John E. Codman exhibited a number of views of scenery in northern New England, after which views of the harbors of Havana, San Juan, and Manila, and a chart of the steaming and sailing routes of the North Pacific Ocean were shown. About forty members and visitors were present.

ABSTRACT OF THE MINUTES OF THE BOARD OF DIRECTORS.

Special Meeting, May 10, 1898.—Present: The President, the second Vice-president, Directors Smith, Humphrey, Levis, Hartley, and the Treasurer. The meeting was called for the purpose of considering the request of Mr. Gwilliam for the use of the club-house as a place of consultation with applicants for admission to an engineer corps which he proposes forming. The permission was granted.

Regular Meeting, May 21, 1898.—Present: The President, the Vice-presidents, Directors Schumann, Levis, Ott, and Smith, and the Secretary.

The Treasurer's report showed :

Balance on hand, April 1st,	$1677 06
Receipts during month,	444 45
	$2121 51
Expenditures,	700 71
Balance on hand, May 1st,	$1420 80

With regard to the investment of $500 of Club funds in an interest-bearing security, the Finance Committee reported that it was considered that the United States Government war loan would be a desirable investment. Figures regarding it were not yet available. Mr. Eglin stated that city loans were also under consideration. Action upon this matter was deferred until the next meeting.

Special Meeting, June 4, 1898.—Present : The President, the Vice-presidents, Directors Schumann, Levis, Humphrey, Ott, and Smith, the Secretary, and the Treasurer.

The Treasurer's report showed :

Balance, April 30th,	$1420 80
May receipts,	425 00
	$1845 80
May disbursements,	288 39
Balance, May 31st,	$1557 41

The Treasurer was authorized to institute legal proceedings against certain delinquents.

ADDITIONS TO THE LIBRARY.

From North of England Institute of Mining and Mechanical Engineers.

An Account of the Strata of Northumberland and Durham, as Proved by Borings and Sinkings.

From the United States Geological Survey.

Eighteenth Annual Report, 1896–97. Part 5, and part 5 continued.

From the Engineering Association of the South.

Papers, Vol. VIII.

From the Institution of Civil Engineers, London.

Timbers of Minas, Geraes, Brazil—Hinton. The Pressure of Grain—Airy. The Cowenhoven Adit-level—Brunton. Maximum Crosshead-velocity—Burls. Slipway on the Hooghly—Callaway. Electric Coal Mining Plant—Gresley. Moving the Station Buildings at Frodsham—Johnston. Repairs at Alderney Breakwater—Townshend. Ceylon Government Railway—Waring. The Manchester Ship Canal—Williams, Eliot, and Meade-King. Rankine's Treatment of the Elastic Arch—Young. Abstracts of Papers in Scientific Transactions and Periodicals.

From Dr. Henry Leffmann.

Under the Yellow Flag.

Editors of other technical journals are invited to reprint articles
from this journal, provided due credit be given the PROCEEDINGS.

PROCEEDINGS
OF
THE ENGINEERS' CLUB
OF PHILADELPHIA.

ORGANIZED DECEMBER 17, 1877. INCORPORATED JUNE 9, 1892.

NOTE.—The Club, as a body, is not responsible for the statements and opinions advanced in its publications.

Vol. XV. OCTOBER, 1898. No. 4.

PROPER PROPORTIONAL PARTS OF ENGINES.

A TOPICAL DISCUSSION.

September 17, 1898.

J. H. VAIL.—I am fully in sympathy with the object aimed at, which I understand is to show, so far as practicable, the importance of standardizing certain details of steam engine parts.

The driving of electric generators for electric lighting, railways, and other purposes, has within the past few years demanded more stringent service from steam engines on the points of regulation and constant operation and extraordinary heavy loads, than had been previously experienced in the various classes of manufacturing, prior to the development of commercial electrical work.

I have had the privilege of receiving a very large number of proposals for steam engines of all types, and have also had to do with the erection and operation of many thousands of horse power. I have made a comparison of some of the details of engines proposed to be furnished, incorporating the same number of revolutions, the same horse power, the same steam pressure, and in other points to operate under exactly similar conditions. I find, by comparing details, that there is a material difference in the sizes and strength of parts from which the same work is expected, such as the difference of forty per cent. in total weight of the engine, which is accounted for in the difference in thickness of the bed-plate and frame, and cylinder walls, size of shaft, and other parts; a difference of thirty per cent. in the diameter of shaft, crank-pin, and cross-head pin, and a difference of from thirty to fifty per cent. in the pounds pressure per square inch on main bearings, crank-pins, wrist-pins, guides, etc., all of which goes to show that if there could be established a recognized standard to which all engine builders would live up, that, other things being equal, the selection of an engine could be more readily made by the intending purchaser.

As previously stated, the driving of electric generators has tended to the development of types of governors that afford far closer regulation under quick variations of load than were ever before attained, and whereas ten years ago it was a stringent requirement to call for a variation not to exceed two per cent. in revolutions between no load and full load, this has been reduced fifty per cent. by possibility of securing engines that do not vary more than one per cent. between no load and full load.

Under the conditions necessary to attain in the driving of large alternating current generators of one, two, or three phase in multiple, we not only expect to secure engines that will not vary more than one per cent. in the number of revolutions per minute under changes in load, but it is an absolute necessity that the variations in angular velocity during any single revolution shall not exceed one-sixth of one per cent. to make it possible to operate such large generators in multiple on the same system.

Certain standards have been established, notably for the manufacture of structural steel, for the testing of boilers, for the testing of electrical apparatus, and on the latter point, probably, the highest accuracy in detail has been attained.

I am sure that the general characteristics of engines can be greatly improved by an effort in a similar direction, and hope that the work of the club in the meeting this evening will be of material assistance.

FRANCIS SCHUMANN.—I fully agree with the views expressed by Mr. Vail. The diversity of opinion on the part of mechanical engineers in designing steam engines is as varied as the number of engineers designing them. It has become so drastic that the attention of engine buyers or users has been directed to this diversity, who naturally ask themselves why one reputable builder should adopt proportions entirely different from those of another, although both are guided by the same general specifications as to requirements. Which is correct? Surely the experience and data available are sufficient to establish some standard, which, if formulated and presented to engineers with the sanction of associations like ours, would be far-reaching in correcting this evil. The question is very pertinent and should receive the careful attention of this and allied associations.

Take, for example, the proportions of the principal parts of an engine, such as the main bearings, crank-pin, connecting-rod, thickness of cylinder walls and of steam parts and pipes, etc. I venture to say that if designs were submitted by a dozen engineers, all guided by the same general specifications as to requirements of duty and general character of engines, no two would agree as to the proportion of the parts mentioned, although the laws governing them are precise, true, and accessible to all.

At the present time we have ample and reliable data which would enable us to classify engines into groups, whether for rolling-mill purposes or electric lighting, and adopt standards for each class. It has been remarked that text- and handbooks do not agree as to proportion; so much more reason for the authoritative establishment of standards.

JOSIAH DOW.—It is evident that the steam engine is not yet a clearly defined engineering construction in the sense that a bridge is; having its variations of methods, yet each sure in detail of dynamic and kinematic meaning to him who will study it in the true light of science and past experience. If this were only a question of determining proper proportions and tensile or torsional strength of parts for some particular design of engine built for the needs of some definite use, we might hope to accomplish the task, but the great difficulty appears to be in the multiplicity of designs and conditions accompanying each—many of them violating technical and scientific principles of steam engineering. We know, however, that there are a few notable exceptions, and to these, I think, we should look for the light needed, aided very much by a few eminent technical students of the steam engine.

A well-known difficulty lies in the demands of many buyers to have incorporated in engines features inappropriate to the particular engine and to the conditions which are to be met, and the too common desire to get "something for nothing" in buying an engine smaller in economy of power than will be required in the near future. In this way the builders are led to make changes rather than to lose a sale; changes in proportions and disposition of parts which are injurious, and confusing to those who look for definite system in their work.

An engine imitated from works having an ably managed foundry and forge-shop, with careful selection of well-understood metal, by a shop not possessing these qualifications, may find parts give out from bad handling in their construction, under ordinary strains, or those induced by faulty workmanship, faulty foundations, or alignment, and in this way radical changes in sectional strength may be thought necessary and afterward permanently adhered to.

The metallurgy of the steam engine is very important in determining the strength and proportions of its parts; the furnaces deliver to us so many grades of iron and steel; the strength of castings depends so much upon the avoidance of internal strains and invisible shrink cracks; while steel or iron can so easily have its strength destroyed by burning in the forge or careless working, that we can only fully determine our sectional areas through knowledge of our material.

Changes in design and every necessity of use may oblige changes in the proportions of particular parts, even when the ultimate power exerted by the engine is the same; *e. g.*, an engine to drive a spinning mill, with its elastic system of belts through which the power is applied, does not require the ability to firmly resist sudden strains which would be necessary in one driving a rolling mill, with its positive and violent changes in application of power, although of the same general design and the same power. Some of the confusion of proportions may have arisen from a cause like this.

It will readily occur to any steam engineer that there may be many other causes for the coming into use of badly proportioned parts of engines, but it seems certain that the evil can not be cured until steam engines are designed, selected, and used under the oversight only of trained experts in the special class of work for which they are adapted. This we are coming nearer to, particularly with the electric installation of the last few years.

Should some genius furnish us with a construction of fly-wheel which will hold firmly together at times which now make it such a source of danger, he would confer a great boon and deserve the gratitude of all steam engineers.

JAMES CHRISTIE.—If we choose some definite type of steam engine—say a locomotive or any class of engine—that similarly permits of uniformity in design, it is, of course, quite practicable to specify a standard of dimensions that will harmonize with the demands of service and conform to some canon of style for appearance. But for steam engines of widely varying design and dimensions, such as marine engines, pumping engines, or engines for miscellaneous power purposes, no such rigidity of dimensions is practicable, for reasons which will be given hereafter.

It is sometimes asserted that a steam engine is susceptible of as exact an analysis as a bridge, as though the designer might calculate a strain diagram for his machine and use that as a skeleton on which to elaborate his working drawing. We can not overestimate the necessity of an intimate and exact knowledge of the acting forces and their distribution throughout the parts of a machine—problems, by the way, which are sometimes extremely complex and frequently insoluble. And it is also essential to possess definite knowledge of the resistance of material to these complex forces; yet knowledge of this kind can be used only as a guide by the designer, and the mechanical engineer will always be influenced chiefly by precedent and experience rather than by calculation. In designing a bridge, the limitation of fiber stress is usually the guiding consideration; but in an engine this is rarely the case; the limitation of deflection is usually the vital consideration. The presence of sufficient material of the right kind in the right place, to prevent undue spring or deflection, is a *sine qua non* to make a good machine, from the structural point of view.

If any person will make a faithful attempt to analyze the forces that act on some particular member of a steam engine,—say a shaft or a connecting rod,—and, after making an algebraic summary of the combinations of tension, compression, and transverse and torsional stresses resulting from forces that are constantly alternating and frequently acting at right angles to one another and, running through the whole gamut of dynamics, attempt to calculate deflections, he will find it necessary to assume a more intimate acquaintance with the theory of strains and the nature of materials than any recorded knowledge will justify. But, assuming that these deflections can be calculated,—for this is within the possibilities of human inquiry and investigation,—we are at once confronted with the problem, What is the proper limitation of deflection? What amount of spring or yield can be tolerated in the member under investigation? This is a question clearly beyond the domain of analysis, and one to be answered solely from experience. Having determined a limitation to deflection for one particular case, can we rigidly apply the rule to all analogous cases? For instance, a transverse deflection, or a torsional yield of a definite extent per unit of length, may safely be tolerated in a short shaft or other member of an engine; whereas the same yield per unit of length might be injurious in a longer similar member. Acceleration of forces or the inertia of moving masses of material must be considered as a determining factor in the problem, and the deflection may have to be limited in extent without regard to the length of the member.

Discussing the subject from this point of view, I have chosen to confine my remarks to the shafts and bearings of engines, and will point out a few reasons why it is difficult to make these conform to any arbitrary standard. The dimensions are determined by two independent considerations: 1. Sufficient size to prevent excessive deflection or torsional yield. 2. To provide sufficient wearing surface; to prevent excessive wear of journals. Usually, when the first condition is preserved, the other is provided for. An old rule which can be traced back to Tredgold limits the transverse deflection of shafts to $\frac{1}{100}$ of an inch per foot of length. This rule must be accepted with reservation. In some cases deflection exceeding this limit is found in no way objectionable; in other cases, not more than half this extent of deflection should be permitted. When the bearings are flexible,—and excessive deflection within the limit of ordinary safety affects nothing external to the bearings,—considerable deflection can be tolerated. When bearings are rigid, or deflection may derange external mechanism,—for example, an overhung crank,—then the deflection must be more restricted. The effect of deflection is to concentrate pressure on the ends of journals, rendering apparent bearing surface inefficient. An example occurs in the modern direct-driven electric generators, which involve unusually long main shafts to accommodate the armature and fly-wheel. Here a deflection of $\frac{1}{100}$ of an inch per foot of length has proved excessive and has caused much trouble from hot bearings. I have latterly proportioned such shafts so that the deflection will not exceed one-half the aforesaid extent.

In some shafts, especially those having an oscillating movement, torsional elasticity is a prime consideration, and the limits can be known only by experience, and will vary under several conditions. Reuleaux says: "Limit the torsional yield to $\frac{1}{10}$ of a degree per foot of length." This in some cases can be readily tolerated; in others, has proved excessive. I have adopted the following as a very general guide:

Permissible Twist per Foot of Length.

.10	degree	for	easy service, without severe fluctuation of load.
.075	"	"	fluctuating loads suddenly applied.
.050	"	"	loads suddenly reversed.

These particular problems of the proper limitation of torsional and transverse deflection of shafts are cited as typical examples of the difficulties encountered in attempting to formulate any rigid system by means of which dimensions can be determined which would apply to any extended variety of designs of steam engines.

Wearing Surface.—When we attempt to formulate any universal system for determining the proper amount of wearing surface or limitation of pressures, we find the problem equally as difficult as when strength or stiffness only are considered. Sufficiency of wearing surface and the limitation of pressure per unit of surface is determined by several conditions:

1. Speed of movement.
2. Character of material.
3. Permissible wear of journals or bearings.
4. Constancy of pressure in one direction.
5. Alternation of the direction of pressure.

The last facilitates complete lubrication of surfaces and permits a greater pressure per unit of surface than the previous condition. Taking the product of pressure per square inch of surface in pounds, and speed of movement in feet per minute, we obtain a quantity, which we can term the permissible foot-pounds per minute for each square inch of wearing surface. This product will be found to vary in good practice under various conditions from 50,000 to 500,000 foot-pounds per minute. For instance, good practice, in later years, has largely increased the area of cross-head slide surfaces, for well-known reasons. For cross-heads having maximum speed of 1000 feet per minute, the pressure per inch of wearing surface should not exceed 50 pounds, giving 50,000 foot-pounds per minute; whereas crank-pins of the requisite grade of steel, with good lining metal in the boxes and efficient lubrication, will endure 200,000 foot-pounds per minute satisfactorily, and more than double this when speeds are very high and the pressure intermittent. On main shafts, with pressures constant in one direction, it is advisable not to exceed 50,000 foot-pounds per minute for heavily loaded shafts at low velocity. This may be increased to 100,000 for lighter loads and higher velocities. It can be inferred from the latter statement that the product of speed and pressure can not be used, in any comprehensive way, as a rational basis for proportioning wearing surfaces. The pressure per unit of surface must be reduced as the speed is increased, but not in a constant ratio. A good example of journals severely tested are the recent 110,000-pound freight cars, which bear a pressure of 400 pounds per square inch of journal bearing, and at a speed of ten miles per hour make about 60,000 foot-pounds per minute.

It would seem that only the broadest and most elastic rules can be adopted in designing machines when stiffness and wearing surfaces are the considerations, and any rule, however flexible, must be taken *cum grano salis*—to be modified and tempered by the judgment and experience of the designer.

Mr. Schumann.—We have a great deal of reliable data similar to that contained in Mr. Christie's presentation, collected by conscientious and able men, covering all the parts of an engine. This information, systematized and brought into rational form and issued as coming from the great engineering bodies, would clear the horizon and be of immense benefit to the engineer both technically and commercially.

The case of the shaft Mr. Christie has just presented is a strong argument in favor of standardizing. Mr. Christie has virtually created a standard for large shafts, he having found proportions which gave the best results. Why should any one differ from him as to the proper permissible foot-pounds on the journals?

Mr. Christie.—The proportions of the receiver depend on several distinct considerations, all of which have some influence—the pressure of the steam, the ratio between the cylinders, and the way they are coupled together, also the point of cut-off in each. The fact seems to be that the capacity of the receiver can be varied considerably without serious prejudice to the final result.

The correct ratio of capacity is determined by so many conditions that you can not settle on any relative capacity and call that correct under all circumstances.

W. C. L. EGLIN.—Mr. Christie has not touched on the question of the reheater. I would like to know his views on that point.

MR. CHRISTIE.—The use of a reheater in the receiver between the two cylinders has received the sanction of such excellent authority that we can not broadly condemn its use. But I know of instances where its use has been positively proved to be attended with loss. I have the records of a case in which 19½ pounds of steam per HP-hour were used without a reheater, which was increased to 20½ pounds with the reheater. The steam was "damp," and the condensation from the reheater was wasted. It is probable that the results might have been reversed if the steam had been "dry" or superheated, and especially if it had been practicable to return the condensation to the boiler by gravity.

L. Y. SCHERMERHORN.—I fail to see how you could standardize the parts of a steam engine any more than you could any other parts of an engineering construction. You are starting from an ideal platform. The parts of the steam engine are to be developed and finally adopted under the light of experience. That question of experience becomes very complicated. A personal equation of the designer must enter into the question very largely. An engineer designs a shaft and bearings and it goes into the hands of a company, who provide the best lubricants and who also provide skill in applying those lubricants to those bearings. The designs are a success. Another adopts the same designs, and they fall into the hands of users who are careless about the lubricants, and still more about the application of them, and it may be that the bearings and shaft fail for that reason. It would seem to me that the personal equations of the designer and user would be necessary for consideration. If the parts of the steam engine are to be thoroughly standardized, then you must standardize the application and the character of the lubrication to be used. You are then introducing elements which are impracticable. Then, again, there is the personal equation of the designer. It is a question of individual temperament and of experience. His design is based on experience not all of his own; it is the results which are derived by the practice of others who are putting in use his designs. His conclusions and practice are based on experience which finally flows from the whole thing. It may be his details have not been closely carried out in their working applications, and this might carry failure with it; whereas the failure was not in the design, but in the operation of the design. It seems to me that that principle would apply which is rightly applied to any other engineering construction. Therefore, I can not see how we can expect, except in comparatively wide limits, ever to standardize the steam engine any more than any other engineering construction.

MR. SCHUMANN.—I differ with the last speaker as to some of the points he makes. The shaft Mr. Christie built and described gave satisfaction, it having proper care and attention while running; and, therefore, a person buying a similar shaft, and ruining it from lack of attention, should be burdened with its cost, because the builder could prove that its proportions were standard and its destruction not due to improper proportions, but due to neglect on the buyer's part. The idiosyncracy of the designer does enter into the question at all. We want the personal equation neutralized by the standards, when it comes to matters of physics. The adoption of standards will not only aid the builder, but will be a protection to the buyer. Instead of waiting for the courts to determine standards through the expensive and doubtful testimony of experts in cases of litigation growing out of unsatisfactory results in the working of an engine, would it not be far better for us to anticipate having accepted standards for the guidance of the court?

MR. SCHERMERHORN.—If you could guarantee that all cylinder walls were to be materials similar in structure, then you might prescribe. We have experience in what walls of a certain thickness have resulted in failure, while another engineer has been blessed with success. Any one, in the light of his experience, is not willing to accept a cylinder of less thickness successful with another, but which has failed with him.

MR. SCHUMANN.—We must, of course, have a material like that contemplated by the standard.

MR. SCHERMERHORN.—Would you rely on a test which could be applied to the material from which steam cylinders are made, and from that test fix the thickness of the steam cylinder, its diameter and pressure being given?

MR. SCHUMANN.—I would fix the thickness of the walls of a cylinder by some of the best examples—the average of the greatest number of them. We have all that information. The data are at hand. It merely means judicious selection. One man has hold of one end, another of the other end, and another man of the mean.

MR. CHRISTIE.—Supposing, for argument's sake, we say it is possible to standardize these things, what object is there in it? I can understand very well why there should be an object in standardizing steam boilers. One should say a boiler should have certain proportions because the community is interested in the safety of that boiler; but in the case of an engine it is not so. It is merely a matter of bargain in purchase and sale between the manufacturer of the engine and the user of it. If the manufacturer is not skilful in his business, and if the machine is not going to be a well-designed machine, and the purchaser is not able to discriminate when he uses a machine of that kind, they are the only sufferers. There are no other parties directly interested. I can not see that there would be any object in standardizing when there is no desire on the part of the purchaser of an engine to get a thoroughly well-made machine.

THE DOW ENGINE (CORLISS FOUNDATION).

JOSIAH DOW.

Read October 1, 1898.

SOME years ago, when George H. Corliss had fully attained the fame and the use of his engine which he so richly merited, it was my privilege to be intimately associated with him, through daily contact, in the study of the principles controlling his great engineering work. From that time onward, as opportunity has served, I have continued these studies and put them into practical use, until now I take much pleasure in presenting, for the first time, before you the description of my own engine, which is the outgrowth of the Corliss, to the inventor and designer of which I am so greatly indebted. It should be clearly recognized that the Corliss engine is not merely a mechanism, but the embodiment of principles in the economic use of expansive steam which have helped more to make the steam engine what it can be in efficiency to-day than any other one cause since the time of Watt.

In view of the important and carefully conducted scientific and technical studies upon heat engines, also the great amount of practical work with them achieved during the past of steam engineering, it is with much confidence that the deductions and final descriptions of this paper are presented as applications of well-established laws and practice.

When, after the year 1849, Mr. Corliss received the first patent covering his new system for the application of valves and valve-gear with a governor-regulated cut-off, he sought a practical demonstration, it was not difficult to prove the superiority of his system over engines constructed with the slide-valve or those giving similar results. The manner in which the first installation in a New England mill was accomplished is familiar to those who knew him well. After much resistance to the use of so new an engine to replace the old system, the bargain was at last made that he should receive for it only the value of such saving in fuel as would be realized within a given time. After one or two periodic payments on this basis, the mill management sought a compromise, which netted Mr. Corliss a profit on his engine far in excess of what he would gladly have accepted in a direct sale. In a few words is here told the real result of the improvement introduced by Mr. Corliss—an improvement which realized the opening of a new system of steam distribution the value of which becomes more evident as knowledge of heat engines progresses. The competition between it and the old, more wasteful system, which ties into an unchangeable sequence the whole cycle of events and necessitates large connecting passages, has reopened in our own day, in consequence of new conditions which have helped the old methods to the front again, while the application of the Corliss method has remained practically where he left it. Yet the new conditions are general in their nature, and, if the Corliss system can be made to partake of their advantages, it should still maintain its original superiority. What are the conditions and physical laws, conformity with which is requisite to the most economic and practical use of steam in a heat engine?

Without critical study of the actions and reactions which control the transformation of the energy of steam into work, it might be supposed that if a certain volume of steam, under a definite pressure, were introduced into a perfectly tight cylinder, from which there could be no radiation of heat, and having a piston which the steam could not pass but only move, that a proportionate energy would be developed and applied to the piston, regardless of any particular form of valve or passages controlling the admission of the steam. But it is soon found that a loss—or, more properly speaking, a wasteful use—may take place of a very large proportion of the contained energy, all the way from the passage at the valve to the completion of the exhaust, and that conditions existing in the valves, the method of their movements, and their connecting passages may greatly change the amount of this loss. In the pipe connecting with the boiler the flow of steam has succeeded in heating the surrounding metal nearly or quite up to its own temperature, and can, with the aid of a good non-conducting covering, hold it with almost perfect success at this degree. Here the problem is more simple, because there are present no influences by which steam, in pipes of ample size and having few elbows, can be reduced in pressure or temperature, except radiation or frictional resistance, the latter being comparatively small, and the former, with modern appliances, almost completely under control, unless the pipe is very long. We may prevent *outward* radiation from the cylinder and spaces which connect the valves with it almost as effectively as with the conveying-pipes; but this is found to remove only the smallest part of the difficulty, because throughout the whole of the inclosed space behind the piston, to the limit of the valve itself, we meet very different and surprisingly active conditions. The most important of these is that, immediately on passing the valve to enter the cylinder, steam comes in contact with a surface of metal much cooler than itself, and in proportion to the *area* of this surface condensation takes place. This refrigerating effect is always present when the steam enters for a new stroke, regardless of how long the engine has been running or how much care has been taken to prevent outward radiation and convection of heat. It is the consequence of a law which is inseparable from the economic—the expansive—use of the steam itself. We are all familiar with the wonderful rapidity with which steam is condensed in a "surface condenser," yet a more efficient surface for condensation, in proportion to the difference in temperature, is often provided in the cylinder and its passages than in the condenser, because water, being a very bad conductor of heat (eighty times worse than iron), the film which forms upon the inner surfaces of the condenser prevents so rapid an action there as would be otherwise possible; whereas the reëvaporation which takes place, during exhaust, of the film of water which has been previously deposited, leaves clear the surfaces to which steam, on entering the cylinder, is exposed, and greatly facilitates the condensation which antagonizes the steam from the very first. To make this clear, let us examine the cycle of events taking place in the cylinder during a single stroke of the piston and its return. When the piston is at its extreme of movement, the valve at that end of the cylinder has opened and steam of full pressure has filled the dead spaces between the valve and the cylinder, and also the clearance-space in the cylinder itself. Then, as the piston moves forward, the steam presses behind it, without stay, until the cut-off point is reached, when the entrapped volume begins its expansion. From the first contact with the cooler and rapidly conducting surfaces which surround it much heat is yielded up, with accompanying and proportionate condensation, which appears to be greatly promoted by the very curious manner in which the rapidly circulating minute globules of water instantly increase themselves. Expansion continues, bringing the steam and surfaces with which it is in contact more nearly into an equality of temperature, when condensation ceases. Soon after, toward the end of the stroke, the cylinder being then hotter than the expanded steam, some reëvaporation begins, —probably very small in degree at first,—in consequence of the non-conducting character of the film of now deposited water. When, at the end of the stroke, exhaust takes place, reëvaporation is instantly and greatly augmented, to which, according to well-known laws, the internal surfaces rapidly yield their heat. This transfer of heat, from the interior surfaces of the cylinder and its connecting passages, continues steadily until near the end of the return stroke, after which a new admission of steam flows inward to come in contact with the now dry, cooled surfaces, and begins the cycle as before, suffering a loss of heat commensurate with the area of the refrigerating contact which it meets. This loss of heat and consequent energy, as we have followed it, becomes finally established almost entirely during the exhaust period, when heat returned to the steam through reëvaporation can deliver no energy to the piston. Instances are given by good authorities wherein, under the influence of excessive dead space and clearance surfaces, with low speed, the proportion of waste from the whole energy of the steam was over forty per cent. As this loss is not caused by outward radiation or convection, and the rapid changes in temperature affect mostly the internal surfaces, a steam jacket can not prevent, or even to any very great proportion reduce it, except with very slow speed. With high pressures and velocities, accompanied by low rates of expansion for each cylinder, as in a compound engine, a good non-conducting covering appears to be quite as efficient, all wastes of the steam considered, while its use greatly simplifies construction. With a lower rate of expansion and greater speed, the loss through internal condensation decreases; but the most efficient help is through a reduction of the dead spaces leading to the closed limit of the valves, with small clearance behind the piston, as in the Corliss engine. Again, the more moisture in the steam as it comes from the boiler, the greater the subsequent condensation, and it is cumulative from cylinder to cylinder in a compound engine. For this reason a careful trapping of all water of condensation from the feed-pipe is important, that the steam may be dry on entering the cylinder.

An important consideration regarding this serious loss of energy is its evident proportion to the extent of the *surfaces* of the clearance and "dead spaces." Therefore, we should aim to not only reduce the extent of the passages themselves, but also such irregularities of contour as may increase surfaces within them with which the steam comes in contact. It has been claimed by some who have constructed engines having large "dead spaces" that an ample compression period to refill these spaces with exhaust steam, forced back again nearly to boiler pressure before the beginning of another stroke, will afford full compensation. To refute this it is only necessary to call attention to the well-established fact that the loss caused by these excessive refrigerating surfaces is consummated really during the exhaust period, when it becomes an actual loss of heat from the cylinder. To recover a large proportion of this loss it would be necessary to restore to its original pressure the larger part of the steam which had just been expanded, and this requires no argument to show what would become of the power of the engine. It is well known that a want of perfectly free exhaust is one of the worst faults in an engine. Again, during the greater part of the compression period, the steam being at that time still cooler than the surrounding surfaces, it continues to reduce their temperature. A glance at an indicator card from such an engine very clearly shows the loss. It is, of course, necessary, by means of compression, to provide a cushion which shall resist such part of the momentum of the reciprocating parts as can not otherwise be effectually used and bring them quietly to rest, thereby avoiding shock at time of the change in stroke, while the resulting work of the momentum can be absorbed in such manner that it may be returned again as useful energy. But it is obvious that an amount of compression which shall require power to accomplish it beyond the value of the otherwise useless excess of momentum must be wasteful. It is also plain that small clearance and "dead" spaces, with a proportionate volume of steam brought to the requisite pressure, will provide as effectual a cushion for the purpose needed as will larger spaces filled with a greater volume, with the advantage of not using for this purpose the momentum, or even the direct force, at a part of the stroke when it is valuable otherwise as useful energy. There should be no waste room in the cylinder or its passages for steam which is simply to react upon itself, while its energy is thrown away through the exhaust. Another means through which much loss of energy may occur is "wire-drawing" of the steam, caused by a dragging action instead of promptness in opening or closing the valves, or through obstruction of insufficient ports. This, however, is so well understood that it is only necessary to call attention to it as a fault to be avoided. The shape of the valves, the arrangement of the sequences of their action, and, consequently, the method of operating them, have much to do with economy of steam-using. They must be applied as closely to the cylinder limit of the port as may be possible, to avoid excessive "dead spaces"; they must not require too much movement to effect the opening and closing of the ports, that promptness may be insured; when closed, they must not offer large surfaces where the incoming steam may be in contact with the partitions of exhaust passages, to avoid an added refrigeration; they must be actuated by the least possible exertion of power; also, separation in body and movement of the valves which control the ports of the two ends of the cylinder is important not only to avoid large "dead spaces," but to give perfectly independent movement to what are independent events.

All these conditions are possessed more perfectly by the Corliss system of valves and their method of application than by any other. Their original advantages can be retained, and the principles which underlie them still further followed out, to increase their efficiency and provide for a uniform travel on the seat for all points of cut-off, thereby avoiding the ridge formed by wear at short range, which, when longer range is reached, causes leakage; an arrangement to provide pressure balance for the valves; an avoidance of the necessity for effecting the cut-off by detachment of the valve from its actuating mechanism, which prevents the closing movement from being positive and in proportion with the velocity of the engine, particularly at high rates of speed, and practically prevents an actuation of the cut-off beyond less than half stroke; also, as a consequence of the last improvement, a uniting of the induction and eduction valves for each end of the cylinder. The gain by the first three of these improvements is obvious. A few words will make clear the advantages of the fourth. Mr. Corliss did not give his engine four valves to each cylinder because of the necessity for saving initial steam from a refrigerating contact with the exhaust valve and its passages, as is sometimes stated, but because, if the two functions were united in one valve, his detachable drop cut-off could not be operated. A little consideration will show that, immediately on entering a cylinder having the valves separated as by the Corliss method, the initial steam fills the clearance space and the dead space before the exhaust valve up to full contact with the valve itself. Combining the valves, while at the same time keeping the passages which lead to and from them entirely separate, not only does away with the necessity for another valve, but also for separate ports, with their consequent doubling of the "dead spaces," while the valve-gear is much simplified. A valve with its functions so combined, however, must possess a positive cut-off action which shall in no way interfere with a perfect timing of its other, or invariable, events, while a careful avoidance should be secured of the jump which occurs, under emergency, with the original Corliss arrangement from a less than half-stroke cut-off to the positive closing action of the main gear near the end of the stroke. When it is remembered that there are four "events" in the valve action for each end of the cylinder (making eight for the complete cycle of movement), which are so distributed that no two take place exactly together,—and all of which, for best efficiency, should be prompt in their action,—also that the movement obtained directly from an eccentric can have but two prompt points, it is plain that any valve action which ties all these events together with such movement must cause some, or perhaps all, of them to suffer drag and disturbance of their proper timing, even if the cut-off could be always held in one place; but with a single valve having variable cut-off—which is absolutely necessary to an economically regulated engine—this difficulty is greatly increased, while it also becomes unequal for the two ends of the cylinder. A "riding cut-off," operated by a second and movable eccentric, is a help in improving the promptness of cut-off for the point at which it is set to work best; but, when that becomes changed, it may even increase the trouble it was applied to remove, and bring a new one with it caused by the excess of angular advance in the two eccentric rods occurring at different times. A similar effect causes conflict between the angular advance of the piston rod, which controls the position of the piston stroke, and that of the eccentric rod, which controls the valve, bringing into operation a difficulty in equalizing the events belonging to the outward and inward strokes—a difficulty which becomes more complicated in its adjustment when another angular advance from another eccentric rod is added. Unequal timing of the events at the two ends of the cylinder will manifest itself in want of smoothness of action. With a single fixed eccentric, however, there are means for effecting an almost perfect correction. To entirely separate the movements of the valves for the two ends of the cylinder, and to give them full efficiency, they should be provided with independent means of action, through which all the events can be accomplished without drag, and the cut-off should be effected throughout its full range with no disturbance of the other events. It was to accomplish these purposes that Mr. Corliss devised the "wrist-plate" movement and the attendant drop cut-off, controlling his light, easily moved valve, so closely seated in the cylinder ports, and with small internal surfaces, from closing of valve to the piston, which, added to the sensitive ease of regulation, afforded the remarkable economy for which his engines have been so justly noted. But these advantages were attained for what is now considered a low velocity. High velocity helps to reduce cylinder condensation, and permits a small, compact engine to be used in place of a large, long, connected one for development of the same power. Such advantages would help the Corliss engine even more than they do, proportionately, the slide-valve engine, which has regained favor by their use. But to realize them the Corliss engine must possess a "positive-motion" cut-off. The "drop and dash-pot" cut-off loses its best efficiency after reaching a speed of about 70 revolutions per minute, and at about 150 revolutions becomes entirely useless without an expenditure of too great a proportion of the power. Here, then, is the feature which has prevented the Corliss system from obtaining the advantages of high speed. The gain through high speed would not by itself have brought the stationary "slide-valve" engine to the front again for the greater powers and more economic uses; but at the same time a form of governor was introduced which, by direct attachment to a movable eccentric, secured an adjustable timing of closure for that form of valve, although it could not release it from the great disability of having all its events tied together, thus producing disorder except for one position of closing.

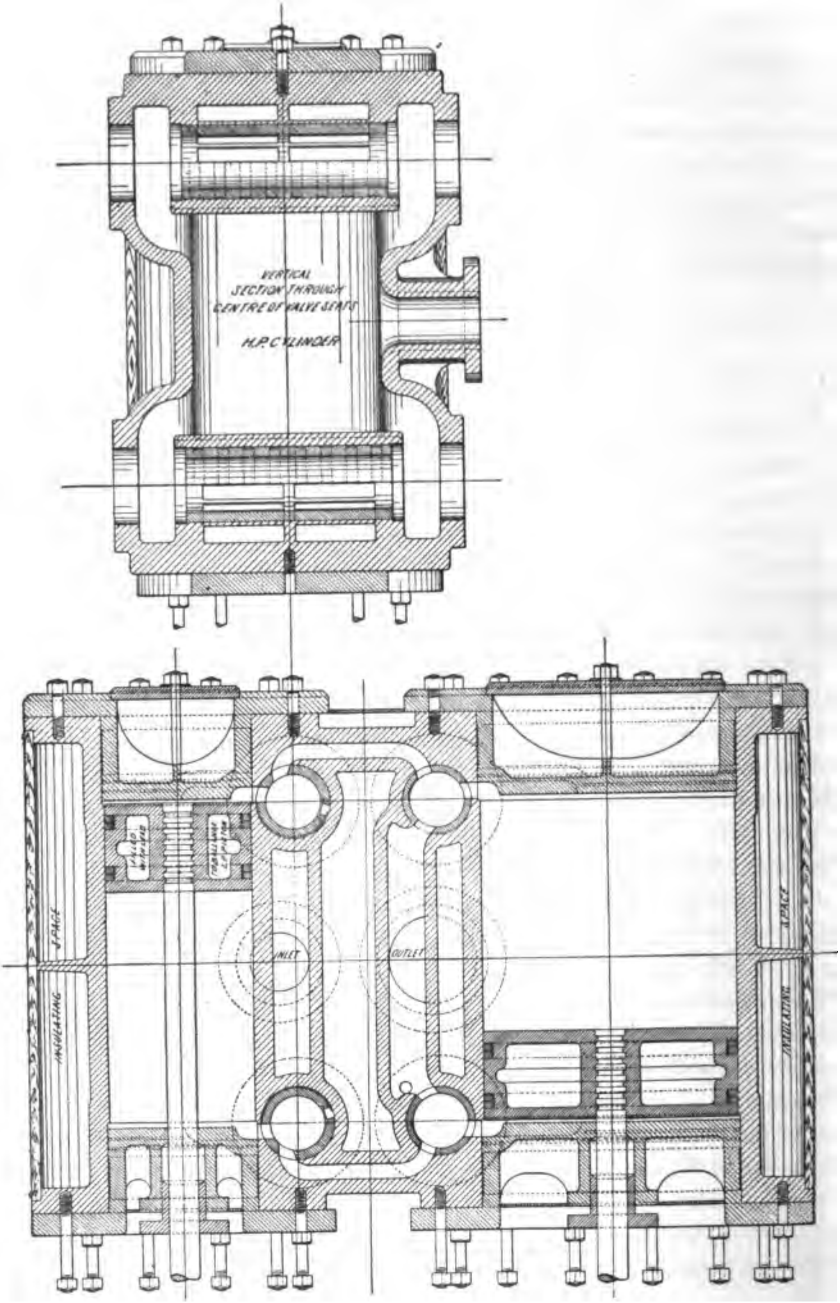
The "shaft governor," with its necessarily heavy masses acting upon a large and strongly resisting valve, did not come into use because it can possess such delicacy in regulation as does the fly-ball governor acting upon a light and easily moved adjusting mechanism, but because its peculiarity of gyrating about the main shaft permits it to be connected to the eccentric cam, through which it can directly hold the valve. A perfect action is very difficult to maintain under its conditions, and the rapidity with which the port is closed is not the same for all positions of the eccentric cam.

A truly economic engine should be designed to utilize high-pressure steam,—120 to 150 pounds at boiler,—because by its use a much greater proportion of the whole energy of the heat can be made available, and because of the boiler economy attainable at high pressures. But at and beyond the limit named new difficulties begin to present themselves, and it is probable that there will be a necessary reaction against the now fast-growing desire to overdo the carrying of very high pressures. Such pressures and consequent thermal limits are impracticable with single cylinders, for they necessitate long range of expansion, with accompanying increase of loss by condensation. The obvious remedy is compounding. As with a proper non-conducting covering the loss caused by cylinder condensation is almost entirely returned to the steam during exhaust, shorter expansion and reuse of the exhaust, having sufficient pressure in one or more additional cylinders, will reduce the final loss mostly to the condensation due to the difference between initial and terminal heat in the last cylinder, *particularly* if care be taken to avoid expansion where it can do no work upon the pistons.

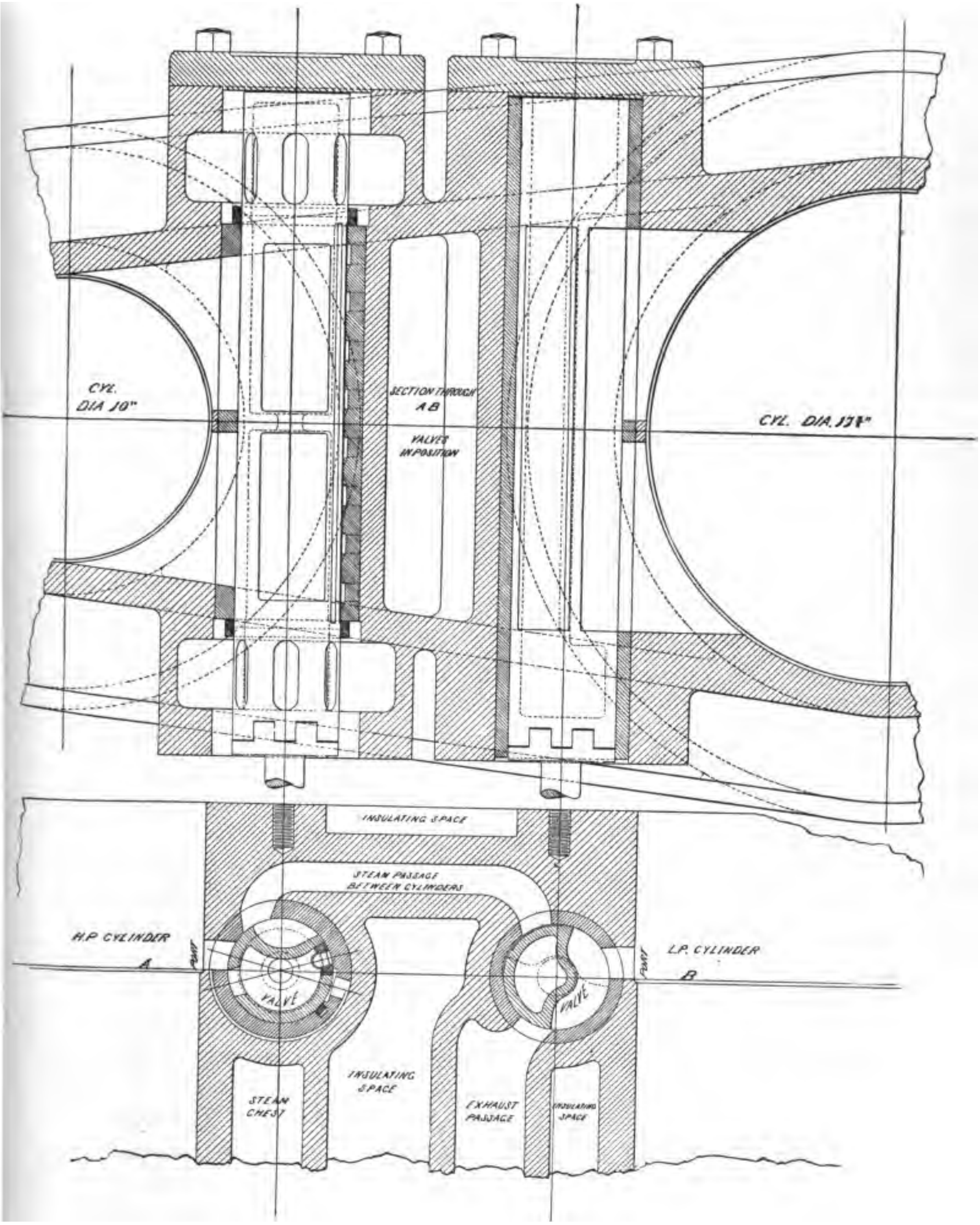
Gravity balance of the reciprocating parts, one against another, is unattainable with a directly connected single cylinder; but with vertical compound engines this can be almost perfectly secured, and greatly assists smoothness of action, with saving of wear. Such an arrangement, with equality of energy delivered by the pistons, also aids in securing balance in the work upon the main shaft, with greatly reduced friction. The often excessive heating of main bearings exhibits the extent to which friction may be a destructive loss. If the advantages of compounding can be secured without necessity for large "dead spaces" between the cylinders, we have a continuation and completion of expansion, from admission to the final exhaust, almost "adiabatic" and perfect in its recovery from cylinder condensation, except as regards the last cylinder. Receivers and large passages between the cylinders of a compound engine, with their additional surfaces to promote condensation, were thought necessary, by their original designers, to provide for an exhaust, which does not coincide with the admission of actuating steam to the next cylinder of the series in crank relation of 90°. An arrangement of the movements of the pistons can, however, be made, which entirely avoids this cumbersome attachment, while at the same time it secures balance of the reciprocating parts, and simplicity in the valves and their movements.

It is not the purpose of this paper to discuss, or even touch upon, every requisite to the attainment of a more perfect steam engine; but to call attention to some essentials which have been embodied in the construction and action of the engine which will now be described.

This engine is a double vertical compound, the present construction using steam of 125 to 130 pounds boiler pressure, and intended to run at about 150 revolutions per minute. The cylinders are placed as closely together as possible, side by side, permitting only room enough between them to provide for the valves, with their passages, and non-conducting spaces to prevent destructive loss of heat, which is further secured through the whole being surrounded by a space filled with an efficient non-conductor, and covered by lagging, preferably of wood. All the valves and steam passages have their positions between the cylinders, not only to avoid any possible loss of heat from them, but to facilitate the transfer of steam from one cylinder to the other and for compactness' sake, with the use of a simple operation of the valves. The final exhaust passage is, however, completely separated not only from its cylinder, but from the steam passages, by ample non-conducting spaces filled, by preference, with "magnesia asbestos." The first cylinder exhausts through very short passages at either end—merely continuations of the ports—directly into the second, the up-stroke of the first coinciding with the down-stroke of the second. The vertical arrangement of cylinders and connections is chosen to aid compactness and to facilitate the desired balance. The vertical form also permits the base and foundation to be compact, which is important when space is costly, particularly in the large cities, where most needed for electrical, traction, and manufacturing purposes. The valves are placed as closely as possible to the interior of the cylinders, as with the Corliss engine, but there are only two to each cylinder, the induction and

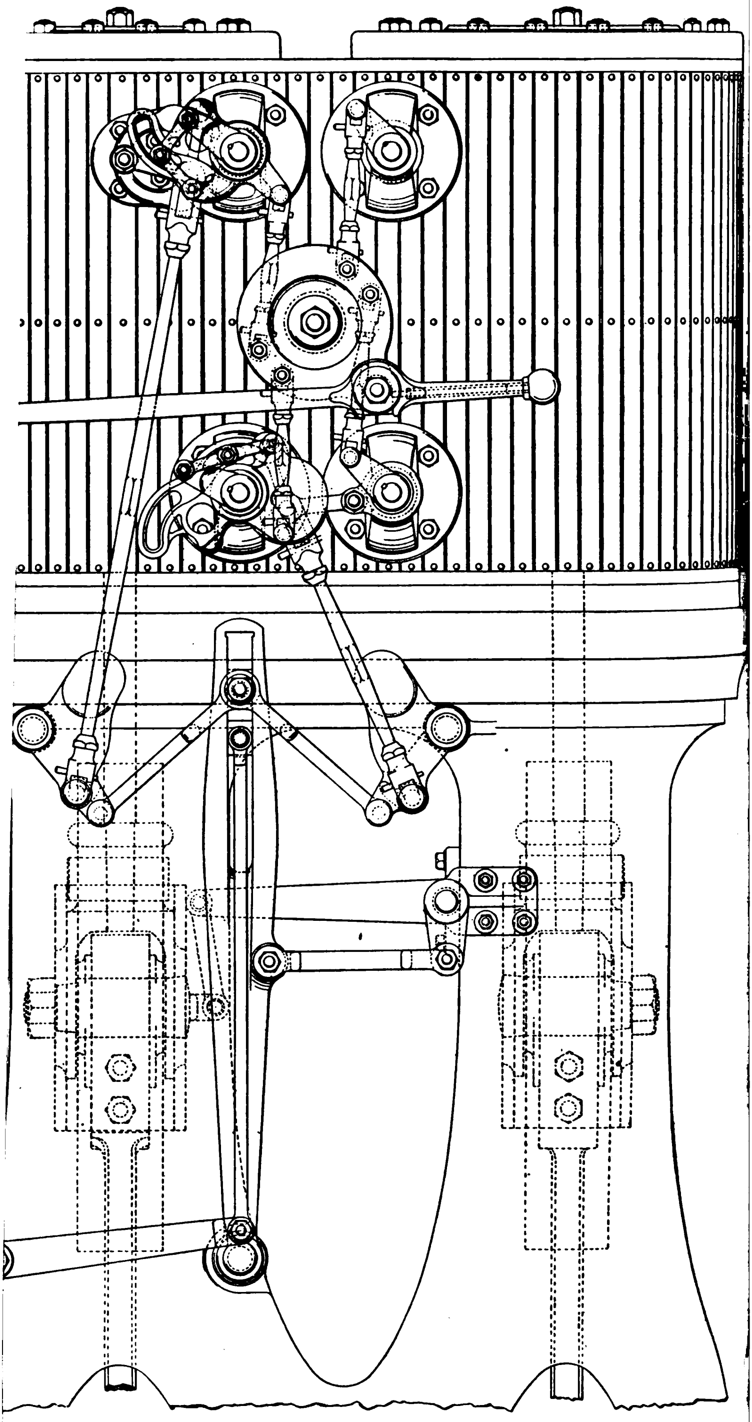


Sections through Cylinders.

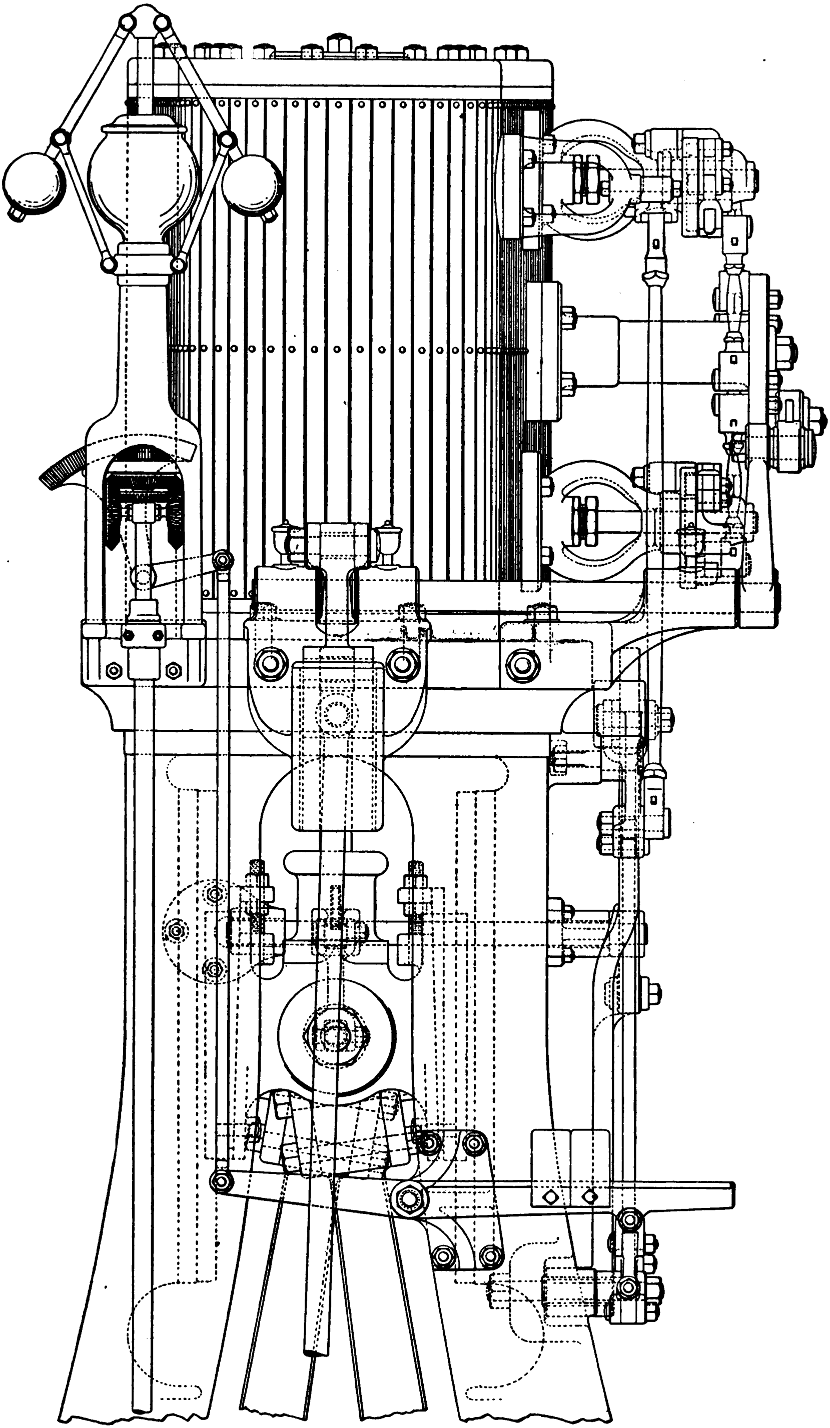


Section through Center of Valve Seats. Cross-section through Valves, Steam Chest, and Passages.

eduction for each end being combined in one; yet the passages for the full steam and the exhaust are completely separated in position and by non-conducting spaces. There are but four valves for the two cylinders, where the Corliss engine requires eight, and all are actuated by one wrist-plate instead of two, as with the Corliss engine. The events of the valves are so arranged that the beginning of exhaust from the high-pressure cylinder becomes directly the initial steam for the low-pressure, the lead for both coinciding and in control of the valve at the first cylinder, the valve at the second cylinder being always open in time to permit its free passage. The work in each cylinder at normal load and pressure is exactly the same, and the weights of the reciprocating parts are balanced against each other by means of the pistons being cast hollow, that the smaller one may be filled with sufficient lead to make its weight equal to that of the larger. The high-pressure valves are cylindric in shape and so constructed that the induction steam passes entirely through them from end to end. The steam chamber is placed directly against the high-pressure cylinder, and at top and bottom is connected with the valves by means of passages in the casting, which lead completely around both their ends, from which, through ample openings, steam freely enters; but to the outside of the body of the valves no steam can obtain access from this chamber, being prevented by packing rings which have their bearings upon seats at either end of the main portion of the valve. In this manner pressure, acting upon the valve, is entirely regulated from its own interior through means of the steam port at one side, and at the opposite side the balance port, arranged with steam-tight packing strips, and with sufficient area to secure a firm seat against both cylinder and exhaust ports, while passages outside the bushing into which the valve fits communicating with the cylinder ports, complete the balance against the changing pressure within the cylinder. The valve receives always the same degree of movement, regardless of the point of cut-off, and, consequently, no ridges can form in the seat where a smooth, perfect contact is maintained, improving with wear, while but little force is required for actuation. Exhaust is effected by this valve through a depression in its side formed to complete the passage which connects the cylinders at the proper time. The valves in second cylinder need no cut-off, its steam expansion being a continuation of that begun in the first; therefore, their construction and action are very simple. They open the connecting passage just before the high-pressure valve releases the steam, and close it with enough time before expansion is completed to leave the steam within it of higher pressure than the terminal of second cylinder; the passage is opened again when compression has brought the pressure in this cylinder back to the same degree, and the completed compression is reached with a pressure about equal to the terminal of first cylinder: this contributes to smoothness of action. These valves also control the exhaust and compression of their own cylinder. Both sets of valves, notwithstanding their own peculiarities, preserve the setting, seating, and movement peculiar to the Corliss system; but, as one valve controls both inlet and outlet, the necessary "dead spaces" at the ports are reduced one-half. The single wrist-plate controlling the main movements of these valves yields its well-known advantage of quickening the action just when most needed, while giving almost perfect rest to the valve during the ingress and egress of steam. The cut-off movement is taken from the "cross-head," that it may be simple in connection and accomplished at identical positions of the piston for both directions of its movement with its own angular advance. This movement is communicated to a vertical lever which has a slot through its upper limits, in which is carried a sliding block, having connection with the governor, from the center of which links are attached leading off at either side to rocker-arms, which also carry connecting rods leading on one side to the upper, and on the other side to the lower, valve-gear. Cut-off is always completed at an identical position of these rockers, and they are so arranged that, if the block is down in the slot, the cut-off will come much sooner than if it be up, the range following such part of the whole stroke as may be desired, from no admission of steam at all to a coincidence with the closing effected by the main gearing at about $\frac{7}{8}$ stroke. The connecting mechanism from the cut-off lever through to the valve-gear is constructed so that only just such part of the whole movement of the lever reaches the valve as is necessary to effect the cut-off, the remainder being lost motion, taken from one limit or the other, according to the position of the block in its slot. This is effected by the rods, which convey this movement to the valve-gear, having certain parts of their movement, when the sliding block is downward through an arc, in movement of the rocker, at the lower end, with a



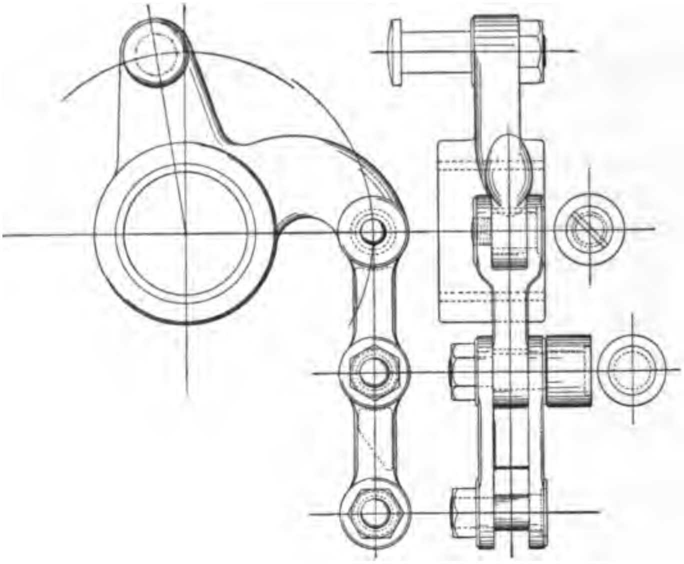
GENERAL VIEW OF VALVE-GEAR AND ITS CONNECTIONS



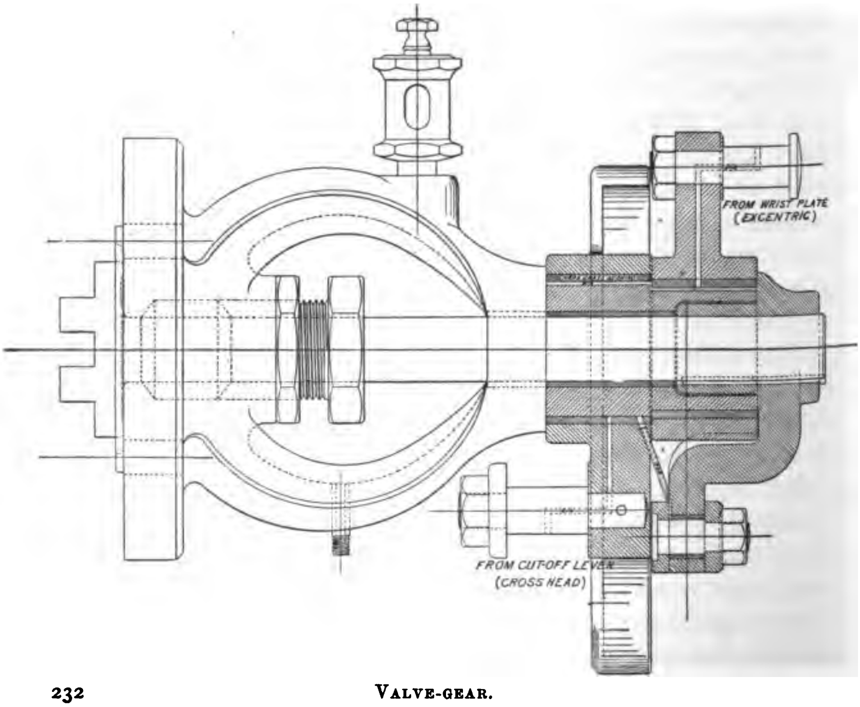
General View of Valve-gear and its Connections.

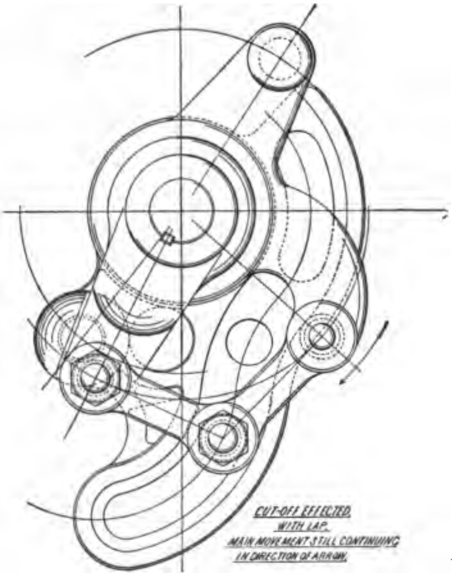
fixed, or nearly fixed, center at the other end, which afterward changes into direct and accelerated movement, through the use, in connecting to the cut-off plate at the valves, of toggle links, which also have the effect of absorbing excess of movement, when the block is upward, to a longer cut-off. This has the effect of making the action of the cut-off very quick where needed, of exactly right degree, and yet with great smoothness and absence of shock when brought to rest in either direction. The block is moved up and down in its slot by the regulating efforts of the governor, and is, with its connections, balanced to reduce its resistance to movement in either direction. As the movement on one side of the lever is effecting a cut-off, that on the other side is restoring the cut-off mechanism to its original position—one action pressing upward upon the block, while the other draws downward. Thus, with such correction for balance in the rocker-arms on either side of the lever as is necessary to equalize their action, they leave the block free to regulation from the governor. The governor was designed purposely for this engine; it is effective, however, with any engine having a true cut-off. It is used in its fullest sensitiveness, and geared to the movement of the main shaft. Its connections through to the block in the vertical lever which actuates the cut-off will be seen in the horizontal levers attached to the side and front of the engine terminating in a vertical rod running up the front of the cut-off lever. Upon the horizontal lever at the side of the engine there is an arrangement for added weights through which a regulated resistance is brought to bear against the actuating gear of the governor, thus determining the velocity of its "balance" and, consequently, that of the engine.

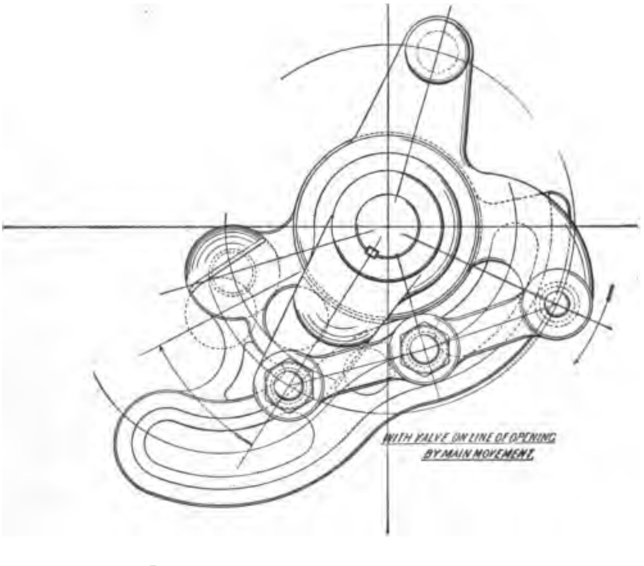
The immediate valve-gear is set upon a "bonnet," as with the Corliss engine. It comprises a crank, having a collar keyed to the protruding end of the valve-stem, immediately behind which is another collar, mounted and revolving upon a bearing at the end of the bonnet. This collar receives movement through a crank cast upon it, with connection to the wrist-plate; it also has cast upon it an arm set in line with the valve-stem crank, to which it is connected by means of two links jointed to each other, to the arm, and to the crank, much after the construction of a "toggle." The center joint of these links carries a strong pin, on which revolves an anti-friction roller, which rests within and follows a groove in a plate set immediately behind the links. This is the "cut-off plate," and has its arc of movement upon another bearing formed on the bonnet end behind the first. The axis of movement of this plate, the arm with its actuating crank, and the crank upon the valve-stem are identical with that of the valve itself. The arc-shaped groove in the cut-off plate, through which the anti-friction roller runs, is also concentric with the axis of the valve through the greater part of its length; and it will be seen that, so long as the roller is held here, the crank which receives movement from the wrist-plate, and that on the stem of the valve, must move exactly together, by which means the valve is revolved to the opening of exhaust, back again to its closing, and on to opening of the steam port, directly from action of the wrist-plate. It will also, in emergency, close the steam port; but the groove in the "cut-off plate" is so arranged that, when the steam port is just fully open, the roller has passed by easy transition into another portion of the groove, being another arc which is concentric not with the axis of valve-stem, but with the center of the pin in the end of its crank, and which has a radius of construction just equal to the length of the link between the crank and the roller. On reaching this changed arc, the roller is carried through it with ready expansion, and as the pin end of the valve-crank is now exactly in the center from which the arc is struck,—the link having the exact length of its radius,—the valve can no longer move, notwithstanding a forward movement of the arm to which the second link is pivoted. The end of the valve-stem crank necessarily keeps its position in relation to the center of the arc in which the roller end of its connecting link is moving, and if the plate is moved, the crank will move with it, only changing the position of the roller in the groove. A leather-covered buffer, however, is in position upon a spur raised from the plate before the valve-stem crank, where it comes to rest quietly through the gradually decreasing motion, controlled by a reverse arc in the groove, which joins the concentric and eccentric portions. The "buffer" simply prevents all risk of strain in the parts at time of cut-off, which is effected by a backward movement of the plate, actuated through its connections to the block in the cut-off lever. The "cut-off plate" is always in position to receive the valve-stem crank in its place of rest, time enough before the beginning of stroke to insure the valve its free opening from the wrist-plate movement, except when, under emergency, the cut-off has acted so early as to prevent *any* opening of the



Details of Gear upon Valve Stem.







Details of Gear upon Valve-stem.

port. Upon the end of the valve-stem crank reaching its position in center of the arc of eccentric groove, the roller moves onward through the groove, while the actuating arm is permitted to approach the crank, through doubling up of the links, and in extreme cases may even start to return in its regular movement before the cut-off, which has more rapid motion, can take place; this may be, under extreme necessity, only just in time to avoid the closing which would be effected by the wrist-plate movement. It will be seen that the anti-friction roller, which runs in the groove of the cut-off plate, is merely a means of guiding and determining the movements of the actuating arm and valve-stem crank, the whole forward movement of the valve being effected by that arm when the toggle connection is in its strongest direct resistance, and the cut-off effected through direct action of the cut-off plate itself upon the valve-stem crank, while the roller permits, at the same time, such free approach of the actuating arm as may be necessary, according to the time of the cut-off. The connections from the single eccentric to the wrist-plate will be readily understood. The arcs of movement in the rocker conveying motion to the wrist-plate and the wrist-plate connection itself are so arranged as to correct the angular advance of the eccentric rod. The main connections of the engine and the bearings are, in every particular, designed to accord with the best practice.

To sum up, we present an engine securing, among others, the following advantages:

In compounding, the second cylinder receives its steam directly from the first through short passages no larger than the ports of the cylinders, and closely guarded against radiation of heat; the expansion of steam, stroke for stroke, being simply a continuation of that begun in the first, without the interposition of a receiver or excessive connecting passages, thereby recovering initial condensation by direct reëvaporation into the next cylinder; also, saving much in intermediate condensation, convection, and radiation, while avoiding the necessity for reheating in an attempt to overcome these difficulties.

The steam chest is between the cylinders, so combined with the first cylinder and its steam passages, so guarded from the exhaust passages, and the whole within so efficient a covering insulating from loss of heat that the smallest degree of loss in energy is suffered from this cause.

The valves—one of which takes the place of two, as with the original Corliss construction—being in themselves continuations of the steam chamber, hold the steam always close against the cylinder ports, while they are balanced for easy action not only against their contained pressure, but also against the varying force within the initial cylinder, thus requiring but little power to operate them, even with high pressures of steam.

Clearance behind the piston, and dead spaces between the closing of the valves and the cylinders, in both cubic contents and area of surface, are greatly reduced, with their accompanying initial condensation. This is largely owing to the advantage of using for both cylinders one port for induction and eduction.

The balance of the actuating parts of the engine, for both gravity and the energy delivered by the pistons, secures smoothness of action and saving in friction.

Great compactness is readily attained, particularly with the vertical construction shown. This gives the engine the advantage, now much sought, of occupying a very small area in proportion to the power developed.

The valve-gear and cut-off are made entirely positive in action, and, while retaining all advantages of the Corliss gear, they avoid the disadvantage of the "drop," and "dash-pot."

A cut-off is provided, always smooth in action and positive in proportion to the velocity of the engine.

These advantages help greatly to do away with the necessity for low speed, which has so much held back the progress of the Corliss system, and a velocity can readily be attained sufficient to meet all needs.

A cut-off can be effected with equal readiness from a point before the beginning of the stroke up to seven-eighths of its travel, where it merges perfectly into the closing of the valve as effected by wrist-plate action alone, with a full opening of the induction port at once, to be held until the point of cut-off, regardless of its place in the stroke, while leaving, as is essential with the Corliss system, all the other events of the valve entirely undisturbed by its change. With the original Corliss engine a cut-off can be effected only within less than the first half of the stroke, while the "drop and dash-pot" arrangement obliges the valve to be kept in motion, with the steam port slowly opening until the cut-off is made.

Our engine effects the cut-off with an equal distance from either end of the piston travel for all points at which it may take place, it being perfectly corrected for angular advance of the connecting rod and consequent position of the piston. This is also true of the wrist-plate connection, which is corrected for angular advance of the eccentric rod.

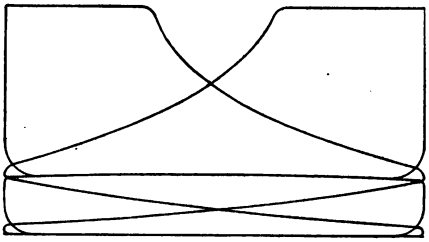
The valve-gear is not only very compact and simple, but always positive in its action, while one wrist-plate for both cylinders directly controls lead of the initial steam, lead of exhaust, and closing of exhaust for compression, the only event separated from its action being the cut-off, which is entirely independent.

The cut-off is controlled by a governor, which is really a chronometric regulator, enabling the engine to quickly and directly effect its necessary changes of cut-off without necessity of waiting for action and reaction of centrifugal force, free from the disability of "hunting," and can, consequently, be used in its fullest sensitiveness, acting with proportionate promptness to the necessary degree of change.

To obtain a reversible engine from this construction it is only necessary to add another eccentric, with a simple link having no intermediate holding between the extremes, because the cut-off, as controlled by the cross-head, will be the same for both directions of movement, and can be regulated, either from a governor or by a hand lever, to the complete stopping of the engine or its fullest power.

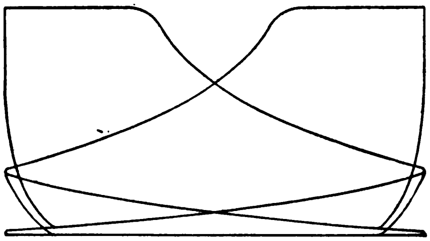
The indicator cards shown are for the purpose of exhibiting, comparatively, the difference in value of steam work obtained in this compound engine and in the older well-known method. They are carefully constructed, without change, except to eliminate vibration of springs, from actual working cards of both engines, the initial pressure, stroke, proportion of cylinders, etc., being made the same; and, as the springs with which the high- and low-pressure cylinder work is recorded are of the same intensity, the relation of each to the other for pressure is correct; but volumes for the low-pressure cylinders should be multiplied by three to make them accord with the actual work in those cylinders, as that was the proportion of compounding in both engines. The loss through the receiver is here clearly shown. It is often almost completely hidden in cards which are taken of compound engines with springs of differing intensity, and afterward reduced to one pressure standard, with distortion in volume and direction of stroke, for a showing of the expansive action of the steam.

Corliss Compound—70 Revolutions, 125 Pounds Steam, Initial.



Non-condensing, With Receiver.

Dow Compound—150 Revolutions, 125 Pounds Steam, Initial.



Non-condensing, No Receiver.

Indicator Diagrams, Showing Difference in Steam Work Between Original Corliss and Dow Engine.

THE DOW CHRONOMETRIC GOVERNOR.

JOSIAH DOW.

Read October 1, 1898.

Isochronous governing of the steam engine, under all changes of load and pressure of steam, has always been found to be of the utmost importance. The means, however, through which it has been sought in the past history of the governor have resulted in destroying stability of action in the parts through which centrifugal force and inertia have been utilized as the controlling principles, and consequently such governors have defeated their own intent in very important needs of their use.

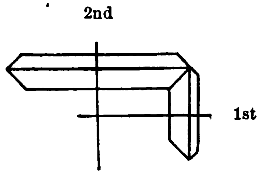
It is often claimed for steam engines that they maintain very close uniformity of speed under all changes; yet analysis of the almost universal methods of governing engines which use steam expansively will reveal often quite serious variations in the proportional admission of steam; and it can not, with the governors now in use, be otherwise, although an aggregate showing may not exhibit it. Apparent uniformity may be intercedent with more or less violent changes, particularly in the true relation of the steam energy applied to the load and the velocity, when taken revolution by revolution; and it would often be not even apparently correct, were it not for the common utilization of the inertia of heavy fly-wheels and oftentimes retarders upon the action of the governors, which would otherwise clearly show their complete inability to establish the required new cut-off under change of load or pressure of steam. The "fly-ball," and all governors which change the cut-off directly through the exertion of centrifugal force working against either gravity or springs, are, if stable in their action, under an influence so exact in its nature that the balls, or weights, are always in precisely the same radial position at an identical velocity. Attempts were long ago made to overcome this by so constructing the fly-ball governor that its balls were obliged to follow a path which would cause their resistance to expansion, by gravity or otherwise, at any position to nearly, or quite, balance the exertion of centrifugal force when moving with the normal velocity. This would, of course, make possible more than one point of cut-off at that velocity; but the arrangement is completely lacking in the first requisite for a good governor,—stability of action,—and has not been successfully used, although modifications of it appear from time to time, except in late constructions, through the dangerous expedient of holding the expansion back from action until the engine is within a small percentage of the normal speed. As expansive change in position of the actuating parts, through centrifugal force induced by difference in velocity, is the direct means by which the cut-off is influenced, it follows with any governor constructed on this principle, and possessing the necessary stability, that the actuating parts, with the rods connecting them to the cut-off mechanism, must be so adjusted that a definite point of cut-off is held with a definite velocity. But a change in pressure of steam or of the resisting load will, of necessity, require a new point of cut-off, to prevent continuance of change in velocity. The governor can, however, only give *one* point of cut-off with one rate of speed, and is, consequently, when trying to meet such changes, always struggling to maintain the normal velocity by "hunting" over the proper point of cut-off, but never able to steadily hold it, unless the conditions for which it was adjusted are exactly restored. Therefore, the chief difficulty arises from the necessary use of such fixed adjustment.

For example: An engine has its governor and connections arranged for a speed of 100 revolutions per minute, with 100 pounds of steam and 100 horse-power resistance in the load carried. Should the pressure of steam be increased or the load diminished, there will be a tendency to "race," which action upon the governor will cause its balls to move to a track of greater radius, thereby shortening the cut-off, and the acceleration of velocity will lessen; but the engine can not, under the new conditions, keep steadily at the rate of 100 revolutions, for that would cause the governor-balls to hold the cut-off just where it was when the racing began—a point which now admits too much steam. Therefore an oscillation is kept up between a longer and a shorter cut-off, until the equilibrium is again restored between the velocity 100, the pressure 100, and the load 100. The manifestations of this "hunting" of the governor in its attempt to establish a new point of cut-off are, for its shorter vibrations, partly held in check by the inertia of heavy fly-wheels; but this does not prevent strains in the connections, which doubtless have been the cause of much trouble, although hidden from ordinary means of observation. Great and persistent changes become more evident, and have been oftentimes disastrous in their results. Governors have been constructed which permit no expansive movement at all, or change in the most open cut-off, until a very near approach to the normal velocity has been reached, when the whole range, to the closest cut-off, is effected within an accession of one or two revolutions per minute. Of course, an engine so controlled may not vary more than two per cent., through control of the inertia of the fly-wheel, below or above the normal rate; but the dangers involved in such violent action and reaction against that powerful and steadying force are obvious, and real steadiness of action through the piston and its connections to the crank-pin and shaft becomes impossible. A hidden evil is always a most dangerous one.

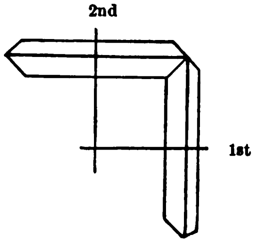
It is plain that a steam-engine governor, to be fully effective, should be as sensitive and prompt in its action as possible. It should act steadily and continuously, even to the full closing of the cut-off, or to its free opening under emergency, yet with the utmost delicacy when under small changes of load or pressure; and, as we have seen that a necessity for tying the expanding parts to the cut-off mechanism so that both must move exactly together has been the cause of its most serious troubles, some other means should be attained which may simply cause the admission of more steam when needed to maintain the normal velocity, or shut off as much as may be necessary, in each case holding the new point of cut-off as readily and steadily as the one from which the change occurred, definitely adjusting to the change which has taken place in pressure or load, and this without extraneous assistance. These conditions can not be covered by the use of a governor which actuates the cut-off directly through the expansive action of centrifugal force, for the reasons shown, and inertia can only act as a retarder of change for a greater or less interval in proportion to the mass of the body through which it is exerted, whether it be in the fly-wheel or the governor itself. To do what is really needed the governor must be not only perfectly chronometric, but truly differential, in its influence on the cut-off, and capable within itself of changing to, and steadily maintaining, any needed point of admission with one rate of velocity. This secured, it can not be too sensitive, for sensitiveness will enable it to effect its changes as nearly as possible simultaneously with the necessity for them. The actuating parts should work rapidly under violent changes, but slowly and more delicately as the normal velocity is approached again, on reaching which there should be, under the newly established conditions, complete rest. A study of these necessities led to the invention of the chronometric governor.

This governor utilizes a chronometric balance, kept in uniform revolution instead of oscillation, and causes the changes of velocity in the engine to react against it, thus directly controlling the cut-off without the delay caused by waiting for the secondary means of centrifugal force which shall return a control to the cut-off connections.

Its action is based upon two well-known mechanical principles: First, if a gear is caused to gyrate about the periphery of another gear, being in mesh with it, as shown herewith, the axis of gyration of the first and that of revolution of the second being identical,—the first obliged to gyrate about this common axis and the second loosely centered upon it,—no motion will be communicated to the second gear, provided its resistance to revolution be made, by extraneous means, greater than that of the first upon its own axis; and there will simply be tooth-by-tooth action as the first gear revolves upon its axis while the second gyrates about the common axis. Now, let independent extraneous forces resist the revolutions of both gears upon their own axes, each for itself; the one under influence of the strongest resistance will carry the other to revolution, the first carrying the second in revolution about its axis without revolution upon its own axis; or the second by remaining immovable, and thus causing the first to revolve as it gyrates about it. But should the second gear have attached to it a balanced mass, increasing in resistance with increase of velocity much as with a chronometer-balance, then it can be caused to revolve by the first gear until its velocity has brought its resistance to a greater degree than that of the first, when no greater velocity can be induced in it by this means, although the gyrations of the first gear may be increased, and thereby cause a proportional

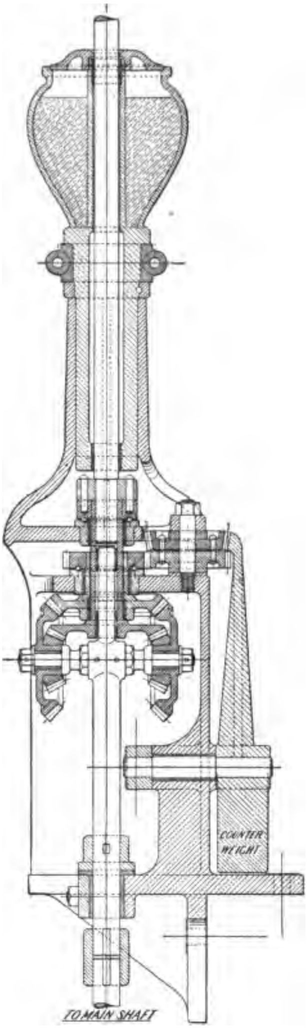


movement about its own axis. Therefore, the velocity which will bring this balance into effect may be readily determined by the measure of the resistance to revolution offered through the first gear. The second principle is that, if two equal miter-gears, as shown herewith, are placed in mesh, the first gyrating about the axis upon which the second loosely revolves, and the gyrating first forced to turn once upon its own axis, while moving once about the axis of its companion gear, it will convey no motion to it, but roll about its periphery, leaving it completely at rest. But, should the number of the gyrations of gear No. 1 be in excess of the number of its revolutions, it will convey a movement in revolution to the second gear, in the direction of gyration, proportional to the excess. Or, should the number of the revolutions of gear No. 1 upon its own axis be in excess of the number of its gyrations about the common axis, it will cause a reverse effect, and will turn the second gear, proportional to such excess, backward from the direction of gyration. In this manner we may obtain, for different proportions of gyration to revolution in the first gear, three different results as regards revolution in the second gear: perfect rest, a forward, or a backward movement, in degree exactly in accord with such proportions.

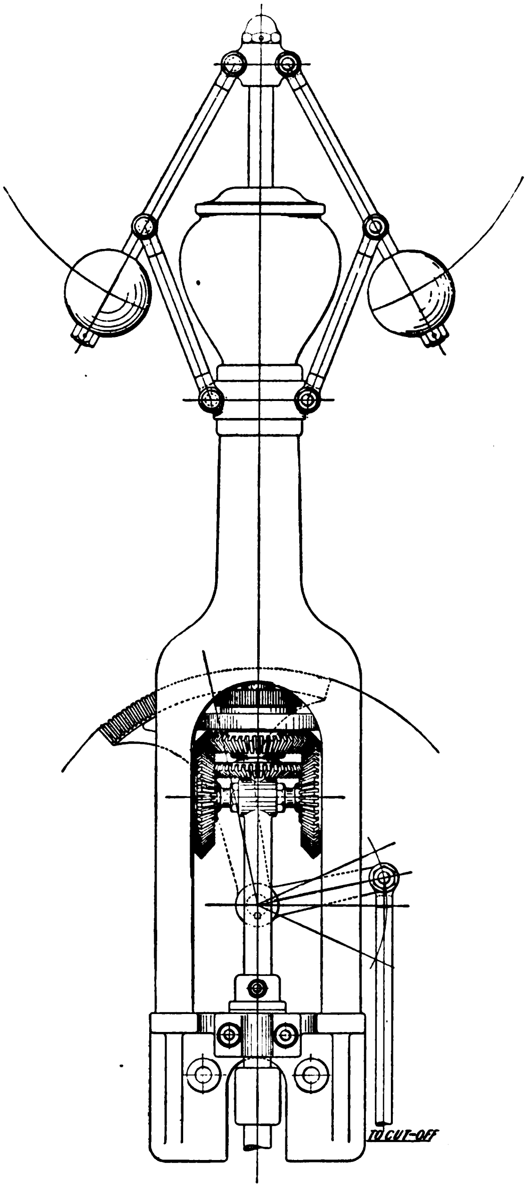


The chronometric balance of the governor now presented is provided with a perfectly controllable and stable regulation through action of the first of these principles, and applies inertia in the most advantageous form, for it provides a standard of velocity against which the cut-off mechanism can directly act without producing change in its value; while the second principle is applied in conveying this action, which is, of necessity, simultaneous with its cause and exactly proportional to it.

The sectional drawing shows a horizontal miter-gear at the top of the train of bevel-gears, having meshed with, and gyrating about, its periphery two vertical miter-gears of equal diameter and number of teeth with itself. These vertical gears have their bearings upon the ends of cross-arms firmly fixed in the main vertical shaft, by which the governor is driven through a direct connection with the main shaft of the engine. The cross-arms give the whole movement to the governor, entirely through action of the differential gearing, the top of the vertical shaft being entirely free from the spindle in line above it which carries the balance, and having its free socket-bearing within the hubs of the horizontal gears. Thus it will be seen that the action of the governor is entirely dependent upon the gyrations and consequent revolutions of the vertical miter-gears, of which, except for the purpose of balance, there need be but one. Keyed upon the hubs of these vertical gears, and therefore moving in all respects exactly with them, are the subsidiary vertical bevel-gears, which are placed in mesh with a horizontal bevel-gear immediately under the horizontal miter-gear first noted. The under-gear has free bearing through the elongated hub of the upper one, and has its own hub still further elongated to receive the spindle of the balance, which in this case is constructed as the ordinary fly-ball, with its expansive movement, to give more sensitiveness in case of emergency. The hubs of both horizontal gears rest vertically through collars upon ball-bearings, that their action may be as free as possible; and it will be noted that these gears are entirely free, in any direct control, one from the other. The two horizontal gears are of the same pitch diameter and number of teeth, the under one being firmly connected to the balance-spindle, the balance moving exactly with it in revolution. The two subsidiary bevel-gears in mesh with this are of exactly half its pitch diameter and teeth, also half that of the gears upon the hubs of which they are fastened, and consequently half that of the meshing horizontal miter-gear. When motion is applied to the driving shaft, the gears upon the cross-arms attached to it will gyrate about the axis of that shaft, and, as this axis is identical with that of the horizontal miter-gear with which the vertical miter-gears are in mesh, they will consequently gyrate about the periphery of that gear and receive revolution from it. If the horizontal miter-gear is held firmly at rest, and the inner train to the balance perfectly free, the vertical bevel-gears, having the same number of teeth as the horizontal, will revolve once upon their own axis while passing once about the other, and their subsidiary gears will also necessarily turn once upon the same axis. Therefore, as the subsidiary-gears have only half the number of teeth of the bevel-gear about which they in their turn gyrate, they can not have a simple tooth-by-tooth action upon it, but will carry



Dow Chronometric Governor.
Sectional View.



Dow Chronometric Governor.
Elevation.

it, for one gyration, by a direct pull to half a revolution, while at the same time releasing it to the extent of their own revolution for the other half of their gyration. Thus it will be seen that the gear which carries the balance is run entirely through pressure—a definite pressure, that which holds the horizontal miter-gear at rest, and which is readily made of such degree that when the inertia of the balance, acting through the train, overcomes it, the horizontal miter-gear itself will revolve, and no further accession of velocity will be given to the balance, although the vertical gears upon the cross-arms may gyrate with greater velocity than the normal. It will also be noted that, under these circumstances, because the "balance" only runs at half the velocity of the gyrating gears under the normal condition of keeping the horizontal miter-gear at rest, and because this velocity of the "balance" is dependent upon a definite pressure which tends to reverse that gear when overcome by the balance, should the driving shaft, with its attendant gyrators, lose a portion of its velocity, that loss will not change the normal velocity of the balance, but will be shown in the reverse movement of the horizontal gear, because the pressure, in this direction, upon that gear being perfectly transmitted to the balance (keeping it in isochronous revolution), and the gyrating gears, under such condition, not passing about the periphery of the horizontal miter-gear with a sufficient number of gyrations to hold the normal relation to it, it must give way—with greater or less rapidity, as need may be—until the normal conditions are again exactly restored. This emergency motion of the horizontal miter-gear is perfectly differential, and consequently in full accord with the need of the engine in rapidity or delicacy of action.

Thus it will be seen that we have a train which will always keep the "balance" running at one regular rate of velocity, determined by the measure of resistance to revolution of the horizontal miter-gear acting against the inertia of the mass in the "balance," whether the engine changes its rate of velocity to slower or faster, or remains at the normal; but that any change in velocity of the engine is simultaneously communicated to the horizontal miter-gear—a forward movement in it accompanying a greater velocity than the normal, a backward movement a less velocity, and no movement at all with the normal. It is by this means that the necessary changes in cut-off of the engine are effected. The horizontal miter-gear has fixed upon its elongated hub a smaller spur-gear, which meshes in the connection, made evident in the sectional drawing, to a sector-gear upon the back of the governor, having upon the shaft of its axis a radial arm carrying the movement to the cut-off of the engine. It is a marked feature of this governor that expansion action of the fly-balls, which may be used as an effective balance, does not have any connection with the regulation of the cut-off; but the balls, in their resistance to change in velocity, governed by the well-known physical laws which control the pendulum and its kindred balancing devices, act in the same manner as does the chronometer-balance, where a definite impelling force always produces a definite rate of motion which can be exactly regulated. This force, the application of which has been described, is determined in its value by weights upon the connecting levers leading from the governor to the cut-off. Expansion is used in the fly-ball balance, and so arranged that the balls will be in a sensitive suspense at the normal velocity in order to quicken the action on the cut-off under emergency. Another marked feature is that, regardless of the degree or duration of a forward or backward revolution in the horizontal miter-gear, upon the normal speed being restored in the engine,—and consequently the driving shaft of the governor, for they should be directly geared together,—the newly established point of cut-off will be as steadily maintained as that from which the change was made, without possibility of hunting, notwithstanding great sensitiveness, because this cut-off actuating gear is then brought to complete rest through the vertical miter-gears simply rolling in exact coincidence of gyrations and revolutions about its periphery, without communicating motion to it, until another change in velocity occurs. It will also be noted that the action in moving this gear is delicate and small in degree, while the variation is slight, increasing rapidly when the disturbance is more important, but decreasing until perfect rest is attained upon the normal being reached again. Transmission of the regulation attained by this governor may be adapted to the peculiarities of almost any form of steam engine. This governor is truly differential in its action, and possesses the greatest sensitiveness to every change in velocity—a sensitiveness which is accompanied by no need of restriction, as it is not attended by any rebound

upon its own action, while the chronometer-like control insures complete isochronism with perfect stability of action, and all degrees of cut-off are controlled with equal steadiness, without necessity for preparatory adjustment to any condition but that of velocity.

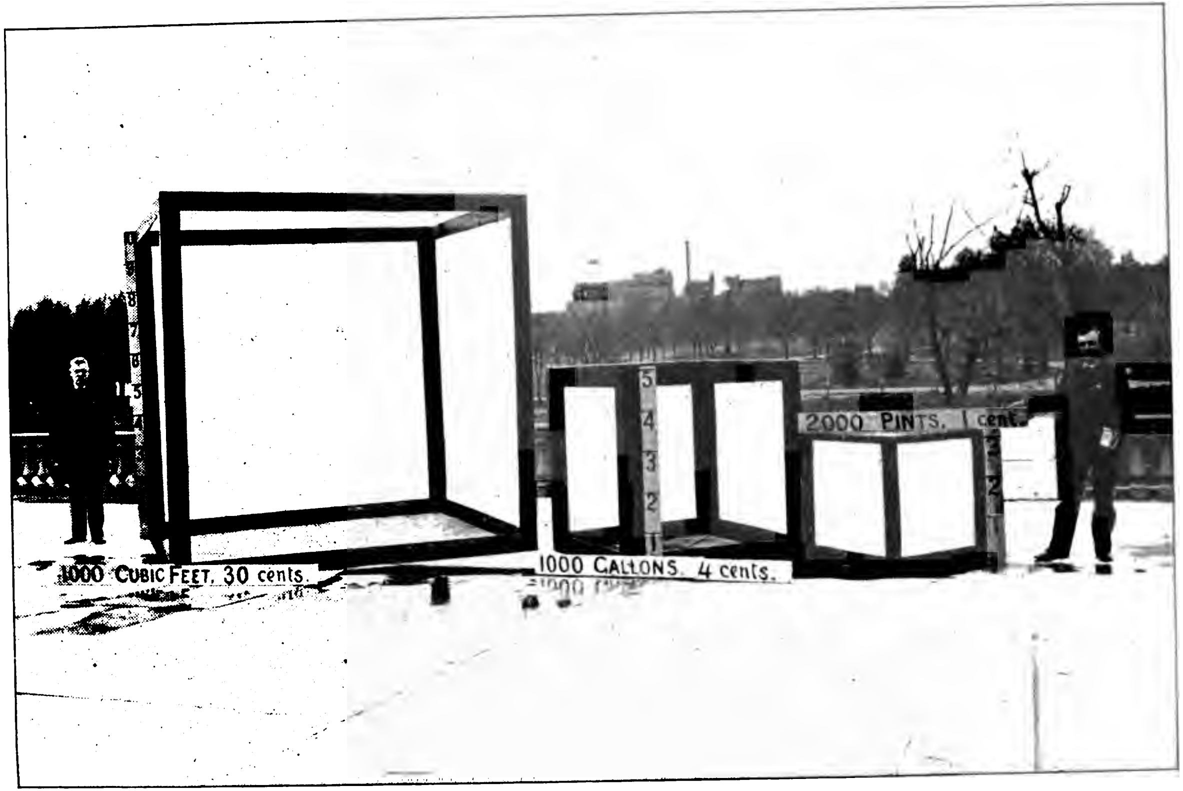
DISCUSSION.

FRANCIS SCHUMANN.—It has been my privilege to examine Mr. Dow's engine and observe its operation. I am profoundly impressed with it, and firmly believe that its advent marks an epoch as important as the invention of Mr. Corliss. With all respect for the opinion of Mr. Dow, as expressed in his paper, regarding the achievements of Corliss in the invention of his engine, I doubt if he is entitled to more praise than Mr. Dow himself, whose engine embraces features far more ingenious and difficult to master than can be credited to Corliss. The positive action of the valve-gear, the balanced valve with the diminished dead spaces, and the action of the cut-off display ingenuity and grasp of the subject of the highest order. The mechanical action of some of these parts is so novel, direct, and practical that it is really a delight to view the engine running. Mr. Dow is the first, so far as I know, who has succeeded in almost perfect isochronism in regulation by the use of a differential governor. I saw the engine in operation when the loads varied probably 10 to 150 horse-power, driving wood-working machinery; the governor was steady in action and adjusted itself practically instantaneously. The steam pressure was 120 pounds at the boilers, yet the valve-gear worked noiselessly and without any apparent effort. When we consider the high rotation-speed, the increased steam pressure, and the extremely close regulation now demanded for the purposes of electrical generators, introduced within the last few years, and the difficulty of meeting these demands with the engines of to-day, we can appreciate the importance of Mr. Dow's forward step. This is the first public notice of the existence of the Dow engine, which I am fully convinced will create a stir in the engineering world.

MR. DOW.—I would like to say a word more. The clearance and dead spaces of this engine have been reduced from what helped so much to save from initial condensation in the Corliss engine. In consequence of taking away the second or separate exhaust port, there is a reduction to about 3½ or 3¾ per cent. of the first cylinder. I think we can safely use these spaces with about 3½ per cent. In the low-pressure cylinder, as it is not necessary to carry the port across the whole diameter of the cylinder, it is about ½ of one per cent. less than that. This is where great economy was effected in the Corliss engine, and I hope for still further progress in this.

A MEMBER.—I think Mr. Dow should tell us of the action of his governor when the load was entirely removed from the engine—that is, the time when the load was suddenly thrown off.

MR. DOW.—I did not intend to say anything about that. It was rather a remarkable occurrence. I did not do it myself, but there was an occasion when it was done. A heavy load was put upon the engine from the shop, which required probably more than double its rated power. The cut-off was at nearly $\frac{7}{8}$ stroke when a clutch upon the main shaft was opened, suddenly throwing the engine practically upon its own friction. The action was so remarkably prompt that a gentleman standing by the engine turned to the engineer and said, "You have broken something." What really happened was that the slide in the cut-off lever came from near the top to the very bottom as quickly as though a sledge-hammer had struck it, and the engine went on at its normal speed. If it would stand that, it probably would stand cutting the belt in two.



"WATER BY THE PINT," AT PHILADELPHIA METER RATES. THIRTY CENTS PER 1000 CUBIC FEET EQUALS SAY FOUR CENTS PER 1000 GALLONS, OR ONE CENT PER TON.

POPULAR ERRORS ABOUT WATER-METERS.

JOHN C. TRAUTWINE, JR.

Read October 1, 1898.

THE waterworks of Philadelphia are pumping more than twice as much water as would furnish to all its people a lavishly bountiful supply at good pressures; yet from all sides come well-founded complaints of beggarly supply and low pressure, the Bureau of Water appeals in vain, year after year, for millions of dollars for new pumps and new mains, and private companies improve the opportunity by suggesting the expenditure of many more millions for prodigious facilities which the city does not need.*

The reason is not far to seek. It is perfectly well known that more than half of all the water pumped is wasted, flowing off into the sewers without benefiting either those who waste it—or the sewers.

If the waste, or even the major part of it, were stopped, the capacity of our works would be practically doubled, and there would be plenty of water for all. The cost of installation of filter plants, or that of bringing water from a distance, would be cut in two. Even without the adoption of means for purifying the water, the quality of that furnished would at once improve, for pumping could then be stopped during seasons of muddy or coal-polluted water, and the water in the reservoirs would have longer time for sedimentation. The minimum flow of the Schuylkill would once more greatly exceed the city's maximum draft upon it, the city's annual conflict with the Schuylkill Navigation Company would be avoided, and the specter of the city's acquisition of that company's properties would be once more suppressed. Finally, the improvement and development of the supply would be brought well within the city's own means.

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* The engineer of one of these companies said to me, triumphantly, "You know very well that the administration that puts meters on this town will cut its own head off." The engineer of another is the only engineer I know who holds that meters are unnecessary.

The restriction of waste is the key to the solution of Philadelphia's water problem.

The experience of other places leaves no doubt whatever that the proper use of the water-meter is a radical cure for the evil of waste, and the only one. In other words, upon the meter depends the salvation of our city's water-supply.

It is, therefore, most unfortunate that, through ignorance of the facts of the case, the public seems to be standing in its own light by a reluctance to sanction the increased use of meters.

Many of our people appear to be under the impression—

1. That the proposed use of meters in dwellings is intended to restrict the use of water.
2. That the charge for water by meter is excessive.
3. That the waste is exaggerated.
4. That the wasted water helps to cleanse the sewers.

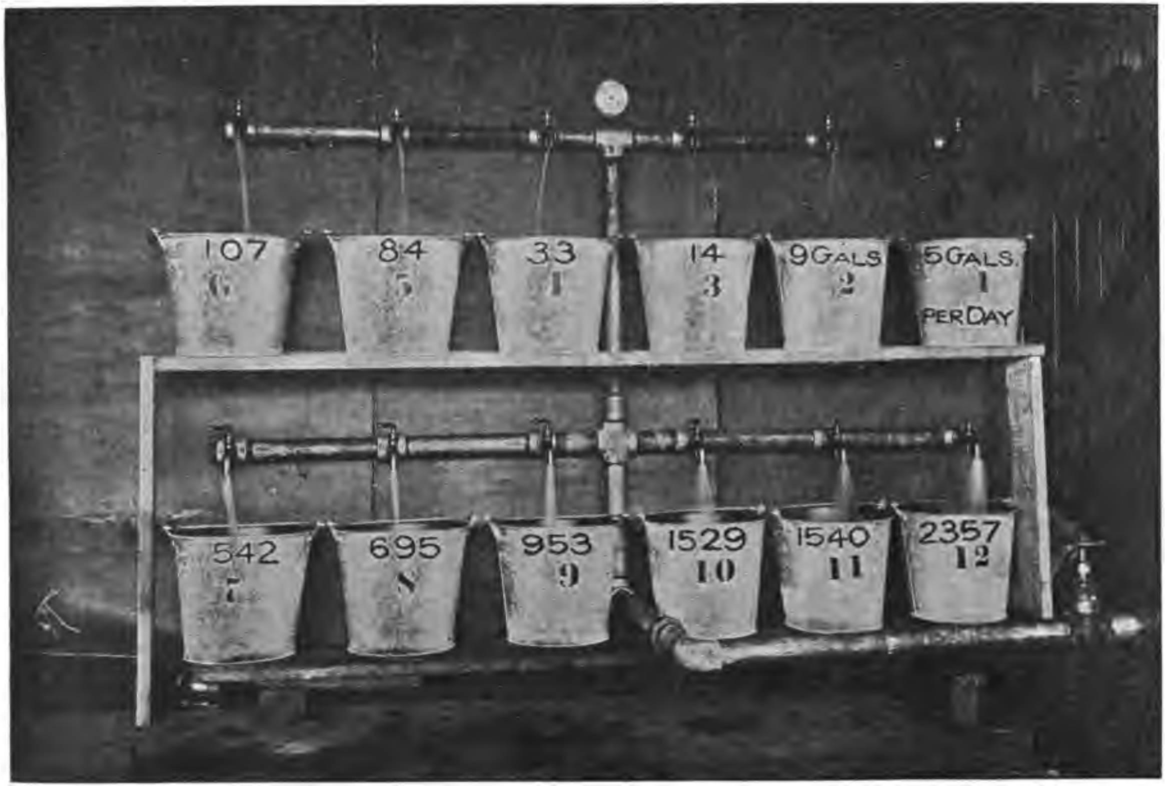
To correct the first error it ought to suffice to say that it is not desired to charge by meter for water used in families.

In the first place, it is not proposed to apply the meter to all dwellings, but to those only where outrageous waste is found to be going on.

In the second place, every metered supply, however little the meter shows, pays a *minimum charge,* established for the express purpose of discouraging economy in the use of water, and in most cases the consumer will have drawn all the water he can possibly use and enjoy, and will have done a fair amount of wasting besides, long before the meter reading equals this minimum charge. The meter thus charges only for water *wasted* (and not for all of that), not for water *used.*

There is, therefore, as a rule, no inducement to be even careful in the use of water from a metered dwelling-house supply, and this is as it should be, otherwise undue economy might lead to filth and disease. Gas may properly be so charged as to induce care in its use, but this is not the case with water. It is better to have a gallon of water wasted than to discourage the proper use of a pint.

That the present meter rate is not excessive is shown by one of the accompanying illustrations, which is simply a graphic statement of that rate. The meter rate (after the minimum charge has been exceeded) is 30 cents per 1000 cubic feet, or about 4 cents per 1000 gallons, or 1 cent per 2000 pints, or 1 cent per ton. One cent's worth of water would supply from five to ten liberal baths, even if



HYDRANT WASTE, 5 TO 2000 GALLONS DAILY. NO. 1 LEAKED ABOUT ONE DROP PER SECOND.

it were proposed to charge by meter for water used for baths in dwellings, or for other domestic purposes.

The other illustration, showing the quantities of water wasted by leaky or open hydrants, indicates one serious source of waste. The hydrant over bucket No. 1 in this view was leaking at the rate of only one drop per second, yet it lost 5 gallons per day. The other hydrants, leaking at different rates, lost from 9 to over 2000 gallons per day each. My bath-room faucet recently began leaking, and before it could be repaired I placed the stopper in the tub, in order to measure the loss. The faucet was merely trickling, yet in the seven hours from midnight to 7 A. M. it put 4½ inches in depth in a tub measuring 2 feet by 5 feet. This amounted to about 20 gallons, or about 70 gallons per day.

Even so trifling a leak, if it existed in each dwelling-house in the city, would amount to six per cent. of our total consumption, and would require an engine pumping 20,000,000 gallons a day to supply it; and it is notorious that thousands of houses have numerous leaks, in comparison with which the one in question is insignificant.

Every one knows that it is a common thing with servants to leave a bucket under a freely running hydrant for hours, in order to draw a single bucketful of water, thereby wasting many hundred times the quantity used.

An investigation of the consumption of the district bounded by Broad, Seventh, Chestnut, and Spruce Streets showed that 63 per cent. of the water furnished to that district was wasted, and by only 17 per cent. of the population, the other 83 per cent. paying for the wasted water.

A similar examination of a district consisting of two intermediate streets in the northwestern section of the city, where 142 seven-room houses built in 1893 were inspected, gave the following results:

Number of inhabitants, ...	539
Number of appliances, ...	782
Number of appliances leaking slightly, ...	22
Number of appliances turned on continually, . . .	32
Average consumption per capita per day, ...	222 gallons.
Water consumed during twenty-four hours, . . .	119,800 gallons.
Water used, ...	16,120 gallons.
Water wasted, ...	103,680 gallons.

In other words, of the 222 gallons per head per day consumed, 30 gallons were used and the other 192 gallons were wasted.

Here, also, a small minority was doing the wasting, and the careful majority was paying for water not received.

A correspondent recently remarked: "It is intensely aggravating to be accused of wasting something we can not get hold of." His trouble is easy of explanation. He had simply failed to distinguish between himself and those who were robbing him of the water he paid for, and he not unnaturally jumped to the conclusion that the Department was similarly oblivious to the facts. Our careful consumers, who are in a majority of about four to one, should understand that the present system makes them pay for the sins of a small but potent minority and go without the wasted water, and that the metering of the supplies of the wasteful few will rectify this glaring injustice without restricting even the wasters in their use of water.

A widow, occupying a house alone, and drawing, possibly, ten gallons per day, pays the same water-rent as her next-door neighbor, who, with the same appliances, has a houseful of boarders, and who thus consumes more than a hundred times as much.

So far from restricting the use of water, the prime object of the introduction of the meter is to encourage that use by making the present supply ample.

The only hardship inflicted, even upon those wasteful consumers whose supplies should be metered, would be that of seeing that their plumbing was in good order, and that no considerable quantity of water ran to absolute waste. In short, in order to keep their bills within bounds, they must take care to use most of what they draw.

As regards hardship to manufacturers, it is to be hoped that no Philadelphia manufacturer is in such straits that he would find it a hardship to pay one cent per ton (or but little more than bare cost) for the water supplied to him by the city; but, if it is considered advisable to give water to any or to all manufacturers at less than cost, the city can do this as well with meters as without them. The meter does not fix the rate. It simply substitutes payment by the ton in place of payment by the year. It encourages and rewards care, where the present method puts a premium on the vice of prodigality.

It is a mistake to suppose that wasted water aids in keeping our sewers clean. This water flows through the sewers with too little velocity to accomplish any good in this respect; but the use of meters would render the supply (with our present means) so ample that water could easily be spared for proper flushing of the sewers by jets introduced at high velocities.

I quote as follows, from correspondence and from publications, respecting the experience of other towns:

Atlanta, Ga.

"There never was a better illustration of the duty so constantly pressing upon municipal authorities to save and protect the unthinking public against themselves and against the consequences of their own want of knowledge as in this instance. The reform was met by a storm of protests, and so great was the opposition that nearly 400 consumers ordered the water cut off. Soon, however, finding that the pressure and service were so greatly improved and the rates with meters really less than they were without, they all came trooping back, admitting their error and full of thanks and praises.

"It was a fight and a sharp one at first, when we put in the meters and filters. Such, however, has been the effect of experience and education, with demonstration of success, that now I make bold to say it would not be merely a fight, but a revolution if we attempted to abolish meters and filters.

"In 1885, with about 2000 consumers, we pumped about the same amount of water per day as we now do in 1895 with over 6000 consumers. Our experience is that, with a minimum rate, consumers use nearly the full amount of water allowed them. The sanitary condition of our city has not suffered by reason of scarcity of use of water.

"We had been pumping 6,000,000 gallons per day, but when meters were put in the daily pumpage immediately fell to 1,250,000 gallons, and the pressure rose to such an extent that we could throw ten or more streams from the street hydrants over the tallest buildings without using the fire engines at all.

"It was the adoption of meters that made it possible to filter the total supply."

Atlantic City, N. J.

"One leaky hopper closet (or one that is allowed to run continuously) in some small property that paid perhaps $6.00 or $8.00 per year on the assessed rate, will waste water enough to supply half a dozen fine residences and sprinkle an acre or two of lawns besides. In cheap houses, or where there is cheap plumbing, by letting the water run to prevent freezing in cold weather, enough is wasted to furnish baths galore to the whole population.

"Considered solely as a cold-blooded business proposition, not taking into account the equity, justice, and other good reasons for its introduction, the meter system in Atlantic City has proved a success.

"This reduction of bills has made the meters quite popular, though there is still occasionally heard the wail of some one who did not have repairs made when he should.

(In Atlantic City the meter rate has been *reduced* from 18 and 14 cents per 1000 gallons to 12 cents, or *three times the Philadelphia rate.*)

"The per capita pumpage has been reduced from a maximum of 260 gallons per day to about 75 gallons per day.

"The results accomplished by the meter system have exceeded all expectations. The waste which has been stopped was greater than any one surmised. Stopping this waste has been a hardship to very few, while the benefit reaches every taxpayer in the city. No one is deprived of an abundant supply."

Utica, N. Y.

"To prevent undue restriction, we charge a minimum rate. With us the use of meters has resulted very satisfactorily. Plumbing is of a better class and our pressure is kept up."

Poughkeepsie, N. Y.

"The consumers soon become convinced that the system is equitable, and it meets with general approval."

Providence, R. I.

"The practical experience of this city in using meters on an extensive scale indicates that the advantages claimed by the advocates of the use of water-meters are not in the least exaggerated."

Milwaukee, Wis.

"Although it was up-hill work for the first two or three years, meters soon became popular. The revenue has steadily increased, the consumption per capita gradually decreased, and the expense of operating kept at about the same figure for the last five or six years. It has removed the necessity of very materially increasing our pumping plant."

Richmond, Va.

"At the commencement of this year we had about 1400 meters in use. I have, so far, set about 500 meters this year, with the result, taken with those previously placed, that the pressure has increased five pounds at the high points, enabling many consumers who had no water on their second floors during the hours of the day to use water on those floors. Our pumpage has been decreased about twenty-five per cent. from what it was four years ago, and we have a larger number of consumers."

Lexington, Ky.

"The only effect of meters is to reduce *waste*, not to reduce legitimate consumption, and a sufficient answer would be to reduce your price for water to any desired amount, ten cents (the Philadelphia rate is four cents) or less if necessary, but let the principle be the same, that each one pays for what he uses or *wastes*. I have not, in eight years' experience, found that the use of meters deterred any one in the slightest from the free and unrestricted use of water.

"The large majority of our customers now prefer the meter system as being more equitable and avoiding the espionage and censorship inseparable from the schedule system."

Harrisburg, Pa.

"We overcame popular objection by teaching people that the only objectors to meters were those who wanted to get water without paying for it. You know, of course, that more than half of your pumping plant would be idle if you supplied water equitably by meters."

JAN 14 1899

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COAL-HANDLING MACHINERY.

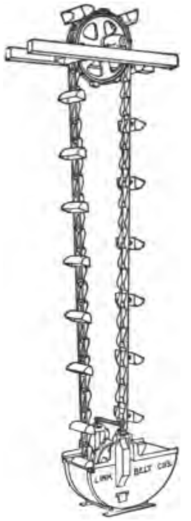
CHARLES PIEZ.

Read November 19, 1898.

THE total coal production of the United States during the year 1896 was 190,500,000 net tons. Assuming that on an average each ton is handled three times from the mines to the place of combustion, we have the equivalent of 571,500,000 tons handled each year. A large percentage of this coal is still handled by primitive methods, and in spite of the economy effected by coal-handling machinery already introduced, it is certain that ten cents per ton would be a conservative average cost for each handling. The handling of coal in the United States represents, therefore, an annual expenditure of approximately $60,000,000, and it is the province of coal-handling machinery to reduce this vast expenditure to a minimum.

The problem of handling coal, as it is ordinarily presented to the manufacturer of this class of machinery, consists in elevating or conveying it, or both, either in its preparation at the mines, its handling and storage between the mines and the market, its storage at retail yards, and its handling at points of consumption. In each case the solution depends upon the distances through which it is to be transferred, the rate of handling to be attained, the size of coal to be handled, the length of service required, and the conditions under which the machinery is to be operated.

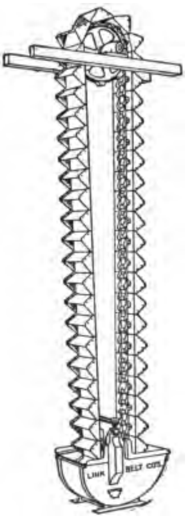
Coal-handling machinery can be divided into two general classes—the continuous and the non-continuous. To the former belong the chain and belt elevators and conveyors, as ordinarily manufactured; to the latter belong the various types of automatic and tub hoists, the overhead bucket tramways, and the cable railways. Each class has its own field of usefulness, and proves highly efficient only so long as it is confined within its proper sphere. Generally speaking, continuous machinery is more efficient than non-continuous because it has greater capacity, is composed of lighter and smaller units, and requires, therefore, less power to accomplish its work. This paper will confine itself to a brief discussion of continuous coal-handling machinery, under the two heads of elevators and conveyors.



CENTRIFUGAL DISCHARGE.

We distinguish as elevators those machines which are specifically employed for lifting vertically, while we distinguish as conveyors those machines which are more especially employed for moving material horizontally. Both classes are often used for carrying material on an incline, so that it is possible to have either an elevator or a conveyor at 45 degrees.

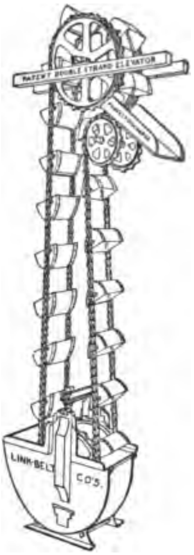
In elevating coal,—more especially anthracite coal,—care should be taken to handle it gently so as to avoid breakage. This breakage is likely to occur either at the point of feed or at the point of delivery. In the common form of elevator, known as the centrifugal-discharge elevator, neither of these points is given attention. This elevator consists of either a single strand of chain or a belt, with buckets at intervals, and depends upon the centrifugal force attained by high speed around the head-wheel for its discharge. The material is scooped up in the elevator boot by buckets plowing through it at a high rate of speed, and when delivered is forcibly thrown against the bottom of the receiving chute, causing very considerable breakage at each end. For the steam sizes of anthracite, and for bituminous slack, this treatment can be endured; but when it is remembered that each per cent. of breakage in the domestic sizes of anthracite coal means a loss of from four to five cents per ton, it becomes evident that an elevator of crude construction can cause more loss from breakage than it saves in the handling. The speed of elevators of this type averages, for coal, about 240 feet per minute, with a 30″ head-wheel, and as the speed is the chief cause of breakage both in the boot and at the point of discharge, a satisfactory discharge at a slow speed, or without reliance upon centrifugal action, must be found to build an elevator which will handle coal without excessive breakage. Three forms of elevator are used to accomplish this: the first is the continuous bucket elevator, and consists of a single strand of chain or belt, with buckets attached continuously. The buckets are of such a shape and so placed that the front of each bucket when inverted acts to complete the permanent chute in receiving the discharge of the material from the bucket following it. This manner of discharge still retains an objectionable element in a slight drop of the coal, but it is a vast improvement over the centrifugal discharge. The action in the boot, owing to the materially slower speed, is also kinder, and the breakage in consequence is materially less. The continuous-bucket form of elevator, while it does not form an ideal machine for the domestic sizes of anthracite, is a compact, rugged machine of great carrying capacity, and is, for this reason, largely employed in the anthracite region. For the steam sizes it is unexcelled as an elevator.



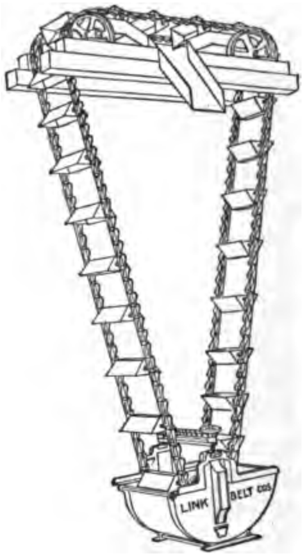
Continuous Bucket Elevator.

The second form of slow-speed elevator is known as the Perfect-discharge type, and consists of two strands of chain, with the buckets hung centrally between them. Deflecting wheels placed immediately under the head-wheels, force the buckets away from the line of the discharge, and allow the receiving chute to be extended to such a point that it will catch the material when it drops, by gravity, from the discharging bucket. This form of discharge entails a very considerable drop, and makes the elevator inapplicable when minimum breakage is the object sought. The elevator has a wide use for materials of a sluggish nature, as the complete inversion of the bucket makes a clean discharge possible.

The third form of slow-speed elevator is known as the Gravity-discharge elevator, and consists of buckets of V-shaped cross-section hung centrally between two strands of chain. The buckets, after passing around the head-wheel, are carried horizontally or on a slightly descending path for a short distance, a trough being introduced under the buckets so as to retain the coal as it flows from the partly inverted buckets. The trough is carried parallel with the line of buckets for some distance, and is then merged into the discharge chute by a gentle slope, the coal being carried along the trough to the point of discharge by the buckets, which act as scrapers. The discharge is effected by flowing, instead of by dropping or throwing, and the most gentle treatment of the coal that is possible is insured. This form of elevator is the most perfect of the three types of slow-speed elevator described, and is largely employed in the handling of domestic sizes of coal.



PERFECT DISCHARGE.

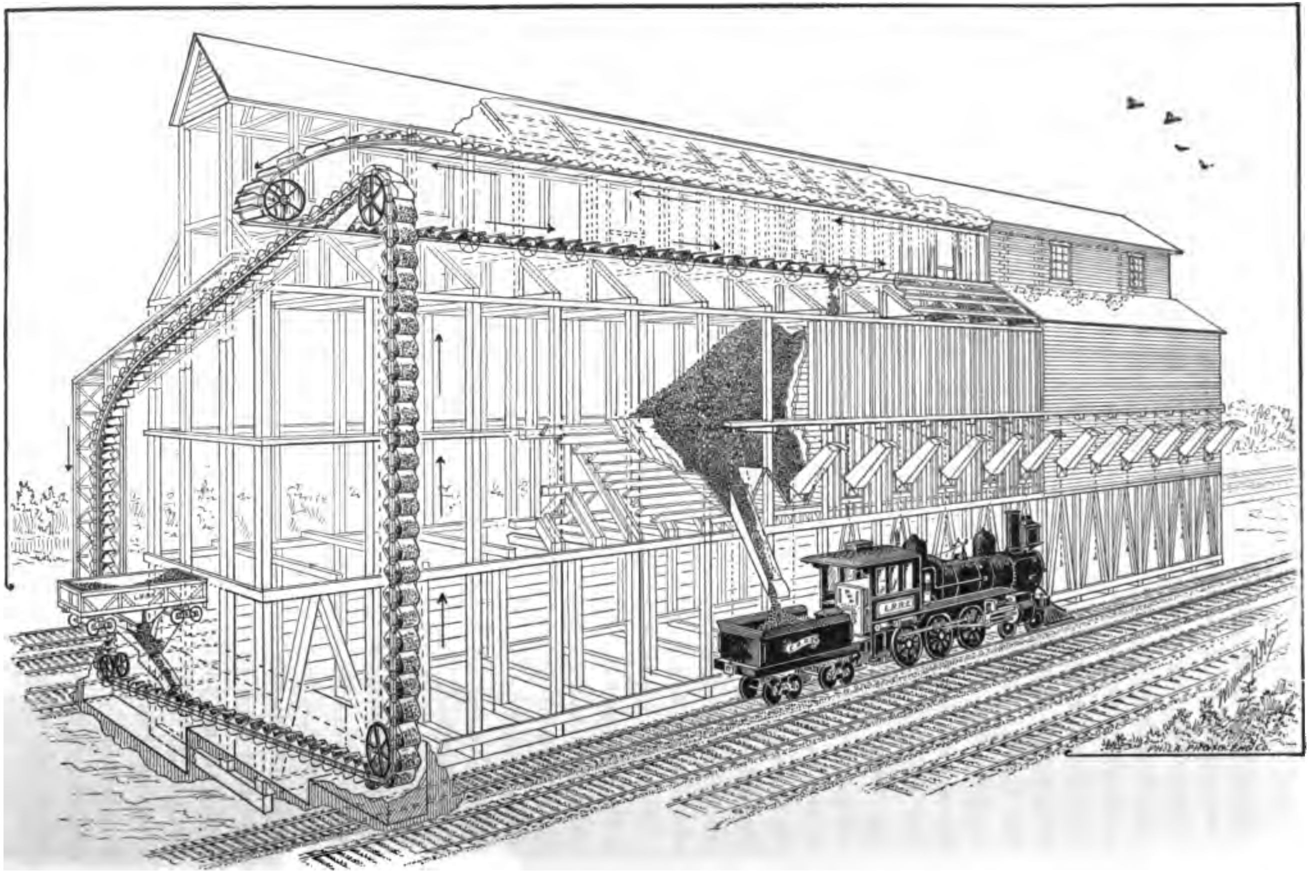


GRAVITY DISCHARGE.

In all the above elevators, the feeding is done by means of a boot, and the safety of the machine depends upon a proper regulation of the feed. To insure this, a regulating gate is necessary, and as these gates, as commonly made, are not automatic, a man is required to operate them. Feeding through a boot, even at slow speeds, is always accompanied by some breakage, due to the dredging of the buckets through the material, and this dredging action is wasteful of power and often dangerous to the integrity of the machine.

To overcome these objections, and at the same time to construct a machine which would render a simple automatic feed feasible, we developed, about a year ago, a form of elevator known as the "Link-belt Carrier Elevator." This elevator consists of a series of overlapping buckets, resembling a series of open-top boxes, set at such angles with the two lines of operating chains that they will carry on two sides of a rectangular path. The lower end of the carrier elevator is extended into a horizontal loop, into which the material is fed by an automatic chute. Material can be fed into either the upper or under run of this loop, as best suits the conditions to be met. In the former case the discharge is effected around the outside of the head-wheels, as in the case of the continuous bucket-elevators; in the latter case the discharge takes place on the inside of the head-wheels, after the manner of the gravity-discharge elevators.

A carrier elevator, with inside discharge, was put into operation about two months ago in connection with a 3000-ton locomotive coaling station, erected for the Erie Railroad Company at Jersey City. The horizontal loop of the elevator extends under two feeding tracks, and coal is delivered into the elevator from two dumping hoppers located on these tracks, the flow being controlled by two automatic chutes. The elevator handles three kinds of coal—lump anthracite (an aggregation of lumps varying from 10″ in length to 30″ in length), rice and bird's-eye anthracite, and run-of-mine bituminous. Lump anthracite requires an opening 42″ wide and 26″ high for a free discharge, and through such an opening the coal, if unchecked, would flow at the rate of from twelve to fifteen tons per minute, fully four times the capacity of the elevator. The satisfactory operation of the machine depends, therefore, on preserving an opening which will permit of a free passage of the coal and providing a means of checking it so that the rate of delivery will not exceed the capacity of the elevator. This the automatic chute accomplishes to a nicety; in fact, so perfect is the control under which it holds the delivery of the coal to the elevator that the two chutes have been used for another and very important function. The smaller sizes of anthracite—rice


PHILA. PHOTO. ENG. CO.

CARRIER INSTALLED FOR ERIE RAILROAD. NOTE: ONLY ONE CHUTE IS SHOWN.

and bird's-eye, the latter of which is only one remove from dust—have a very limited market, compared to their production, and form, therefore, the cheapest kind of anthracite fuel. In order to render them available for locomotives, they are mixed with a small proportion of bituminous coal, which forms a binder and keeps the anthracite on the grates. The Erie Railroad Company uses this mixture very largely, in the proportion of two parts of anthracite to one of bituminous, and this combination is coming into use with other anthracite burning roads. This mixture, if it can be readily and cheaply effected, forms the cheapest fuel known.

The mixing, in the coaling station referred to, is accomplished by dumping the two kinds of coal simultaneously into the two track-hoppers, and adjusting the automatic chutes so that one will fill the buckets two-thirds full with anthracite, and the other will supply the other third of bituminous. In discharging from the elevator into the distributing conveyor, the charge of each bucket is overturned, and this is again done when delivering into the bins. The product is well mixed and highly satisfactory.

In all elevators the weight of the machinery, as well as the weight of the material, is carried directly by the chain, and for large capacities and high lifts this weight assumes very large proportions. It is absolutely essential, to insure durability, that sufficient bearing surface be provided to reduce the pressure per square inch to an amount which will preclude cutting and gouging. A chain with a working strain of 6000 pounds should have twice the bearing and sprocket surface of one having a working strain of 3000 pounds. This is axiomatic, yet it is rarely given any consideration by the purchaser. He compares chains only by the tabulated working strains, and rarely pays any attention to the area of sprocket and bearing surface, or to the character of materials constituting the chain journals.

A very glaring case of the disregard of this fundamental truth of chain design came to my notice some weeks ago. A new sugar refinery in the vicinity of New York had a problem of receiving coal from cars, lifting it 90 feet, and distributing it into an overhead bin 50 feet long. This would strike even a layman as a problem of elevating and not as one of conveying; yet it was solved by the use of a pivoted-bucket conveyor, which, while a very excellent machine as a conveyor, was out of place as an elevator. The weight of the machine and coal was, roughly, 100 pounds per running foot. On horizontal runs, machines of this type require about five per cent. of the total weight to move them, so that the strain for the lower horizontal run, which augmented the strain at the head-wheel, was about 250 pounds. The strain due to the vertical lift was 9000 pounds, making a total of 9250 pounds. The total bearing surface provided was that given by four straps $\frac{5}{16}$ of an inch thick articulating on a 1-inch pin, or $1\frac{1}{4}$ square inches of projected area. This gives a unit bearing strain of over 7400 pounds, which is far too high to insure even reasonable durability. The criticism made is not against the machine, for under certain conditions it is a highly satisfactory conveyor; but it is against its use as an elevator of this height, for which its construction is entirely unsuited.

The problem of conveying coal is one that often presents itself with the problem of elevating, and the tendency in recent years has been to construct machines which will perform this double function. This tendency grew out of the desire to avoid transfers, with the accompanying breakage and danger of accident, to save power, and to simplify its application.

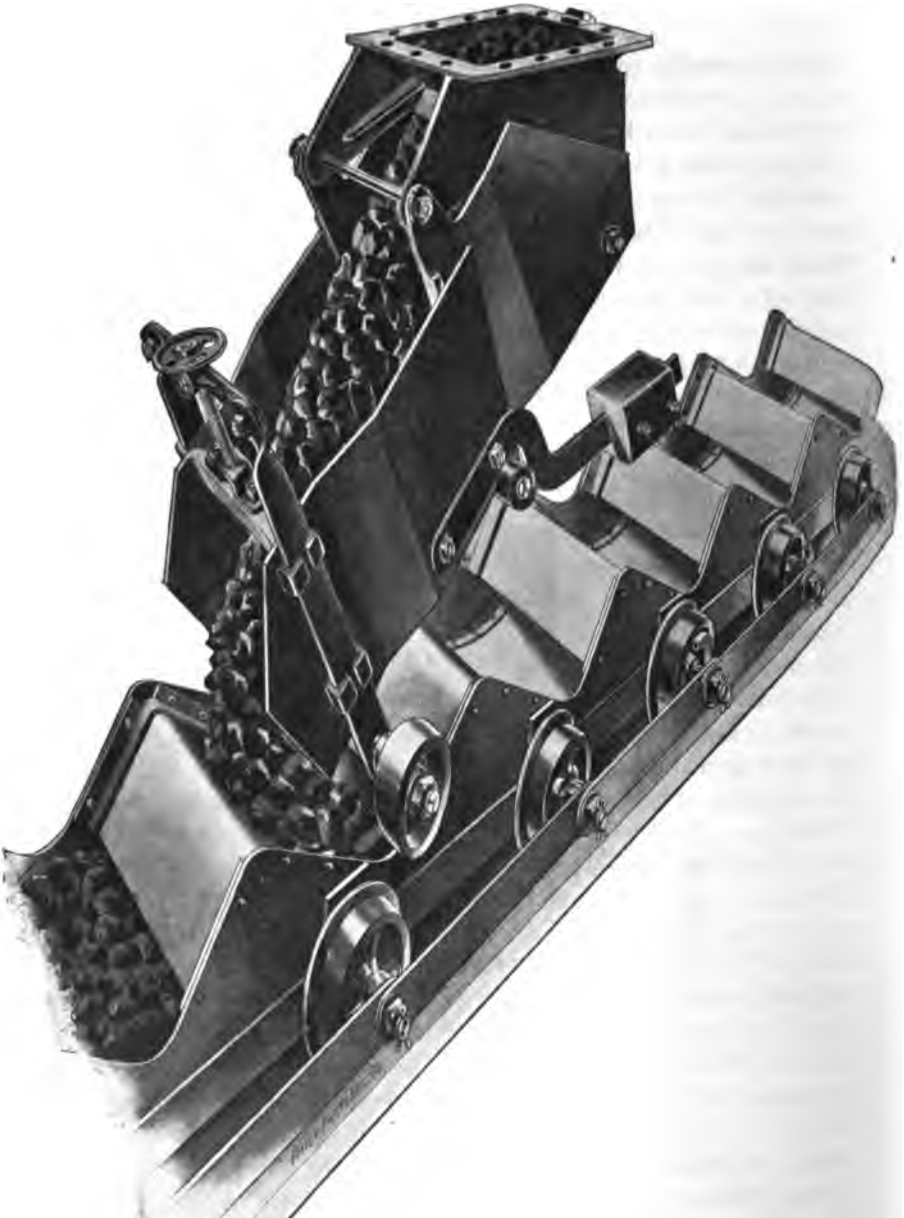
The first solution presented was that employing a series of buckets suspended pivotally from two strands of chains. As the entire weight of machinery and load is thereby thrown on the chains, these are fitted at the points of articulation with flanged rollers. The buckets are suspended from points a little above their centers of gravity when loaded, so that they will remain right side up, no matter in what direction they travel. They discharge by upsetting against suitably placed tipping blocks, which can be shifted at will. In order to reduce the shock of the blow, the point of suspension must be placed as low as possible, rendering them slightly unstable and necessitating slow speeds to prevent them from upsetting when rounding curves. This potential instability, as it might be called, renders careful loading necessary, and it is here that the great weakness of this machine exists. The small sizes of coal run freely through small openings, and can, therefore, readily be controlled by throttling the orifice. But the larger sizes require openings which, if unchecked, would swamp the conveyor. In some experiments made by us several years ago, on the flow of coal through discharge openings in hoppers, we found that egg coal required, under a head of 5 feet, an opening 18 inches square, to flow without choking; and that through this opening it discharged at the rate of five tons per minute. Even a slight reduction in the area of the opening resulted in the bridging of coal across it, and in a total stoppage of the flow.

As the buckets in this form of conveyor swing freely on pivots, great care must be exercised in loading them centrally and uniformly, to prevent harmful oscillation; and any one-sided load or overload is apt to result in a premature discharge. Very ingenious methods of filling the buckets have been devised, the most usual consisting of a short conveyor encompassing the delivery chute, and consisting of a series of rectangular funnels of such shape that they will bridge the gaps between the conveyor buckets and place a very much constricted opening centrally over the bucket to insure proper loading. For handling large anthracite or bituminous coal the filling device fails in two respects:

1. It greatly reduces the discharge opening into the bucket and is of such a shape as to invite bridging across this opening.
2. It is in no way instrumental in checking the flow of the coal and preventing an overload.

The overlapping pivoted bucket, while it has the advantage of preventing leakage between buckets, and can, therefore, be loaded without the intervention of a filler when small coal is handled, shares the disadvantages of the older type in the handling of the large sizes.

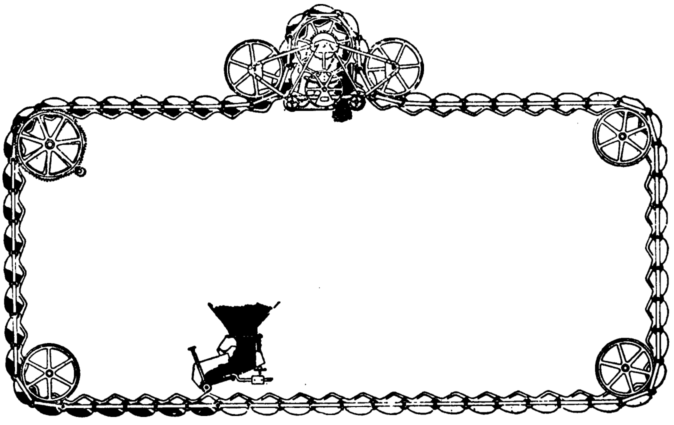
The problem of providing a method of feeding bucket conveyors which would dispense with the man at the feeding gate, and would, at the same time, insure a uniform delivery, engaged our attention for some time about three years ago, and resulted in the development of the "Link-belt Automatic Chute," and its corollary, the "Rigid Bucket Carrier." The carrier is called a corollary of the automatic chute because, upon determining what seemed the only satisfactory form of chute, we found it could be operated only in connection with a rigid bucket conveyor. An accurate idea of the operation of the chute can be obtained from the illustrations. It consists, briefly, of an upper part, which is adjustable as to pitch, to suit the varying degrees of mobility of the material to be handled, and a lower hinged end, operated by the cam-shaped sides of the buckets. The underlying principle of the chute is the preservation of an area of orifice which will insure a free delivery, the regulation of flow being accom-



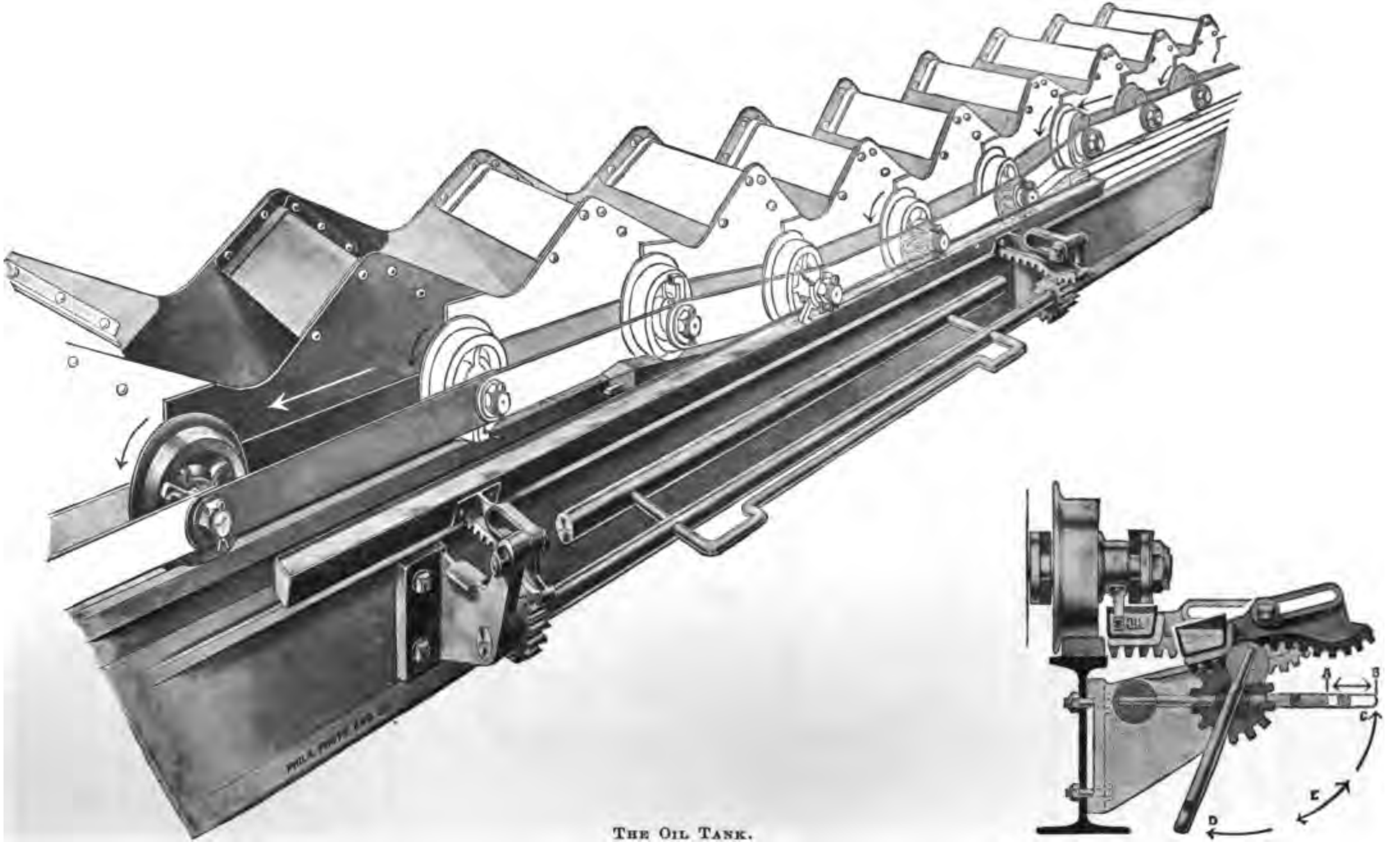
The Automatic Feed-chute. In Low Position—Delivering.

plished by bending up the stream, after it has passed through the orifice. The limit of its capacity as a regulating device has already been referred to under the head of the "Carrier Elevator."

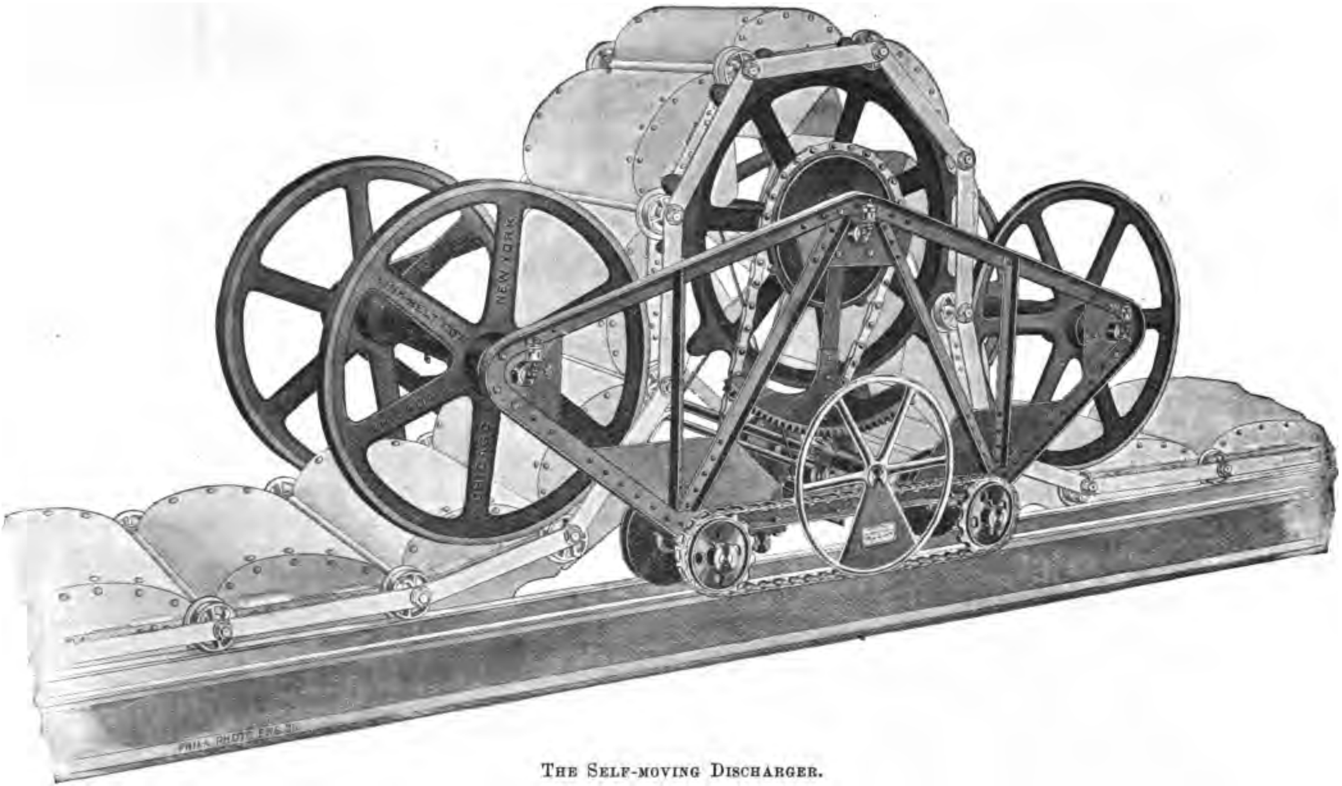
The rigid, or, as we style it, the "Link-belt Carrier," can be briefly described as a series of overlapping buckets rigidly connected to two strands of roller chain. The buckets are fitted with hoods, partially closing the tops, and of such shape that they will carry on three sides of a rectangle. They are discharged by passing around a *dumping carriage*, which completely inverts the bucket. The carriage is movable at will, in either direction, by power, and affords a very easy method of changing the point of discharge. For a carrier having a capacity of 70 tons per hour, the discharging carriage takes up 6 feet in height, by 3 feet in width, and this is sometimes urged as an objection to the machine, because space is an object. The discharging carriage is necessary in a rigid bucket machine just as it is in a belt conveyor, and when space is an object, it is simply a question whether it is worth more than the man at the delivery chute. The carrier has another interesting feature, and that is the self-oiling roller. With the large number of rollers employed in a machine of this type it is essential to even reasonable durability to provide some effective means of getting oil into the journals. This is accomplished in the link-belt carrier by using rollers having chambered cores con-



LINK-BELT CARRIER.



THE OIL TANK.



THE SELF-MOVING DISCHARGER.

nected by oil slots with curved hollow fingers adapted to pick up oil from a narrow tank located in the path of the fingers. This method of oiling flushes the journals and lubricates the joints of the chain as well. This is accomplished automatically, and the only labor involved consists in filling the oil tanks whenever oiling is necessary, and occasionally inspecting the oilers to prevent clogging.

The various forms of bucket machines just described are combination machines, and are rarely used for direct horizontal transfers.

There are four distinct types which are used for this purpose—viz.:

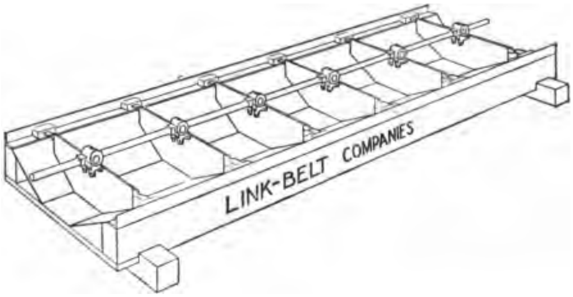
1. Screw conveyors.
2. Scraper conveyors.
3. Belt conveyors.
4. Continuous rigid bucket or pan conveyors.

Screw conveyors are so well known that they require no description. They occupy very little space, and on this account are often used for short conveyors handling small coal. They are, perhaps, the least expensive of the various forms of conveyors, but have a number of serious disadvantages which render them unfit for consideration, except where small quantities of fine sizes of coal are to be handled. When used in coal, they should be constructed with heavy steel or cast-iron flights secured to extra heavy pipes, and the journals shôuld be hardened and run in chilled bearings fitted with compression grease-cups.

The scraper conveyor, consisting of a line of scrapers connected by a single or double strand of chain, and running in a steel trough, is the most vehemently condemned, but, in spite of this, the most widely used of the many forms of conveyors.

The most common objections urged against it are that it is exceedingly wasteful of power and that it is objectionably noisy. The latter objection was undoubtedly made with considerable justice against the earlier forms; in fact, the validity of this objection is vividly recalled to me by the remarks of one of our customers, who, after the test-run of the first scraper conveyor installed in his establishment, about seven years ago, pronounced it a "howling success"; and I agreed with him at the time—it was a howling success. The howling, or rather squealing, is due to the vibration caused by sliding a thin blade edgewise along the trough, and is readily and effectually overcome by the dishing of the scraper, the thickening or flanging over of its bearing-edges, or its suspension from suitable guides by means of cross-bars and wearing-shoes.

The first objection—namely, that the scraper conveyor is wasteful of power—is untrue. What is true is that it takes more power than does a properly designed bucket conveyor to carry a given quantity of coal a given distance; but this excess of power brings some compensation, and can not, therefore, be called a total loss. In bucket conveyors the saving of power is gained only by the addition of very considerable weight and considerable expense. In fact, for machines of similar capacity a bucket conveyor will weigh four times as much as the running parts of a scraper; and even though the rollers reduce the friction from one-fourth to one-fifth, there is very little difference in the power required to move these machines empty. It is only when carrying coal that any material advantage is secured by the bucket conveyor, and then the difference amounts to but 2½ horse-power per hundred feet, for machines having capacities of thirty tons per hour. Perhaps the name of "scraper conveyor" has been as potent in raising prejudices against it as any other single cause. Scraping is always associated in our minds with noise and commotion; as a matter of fact, the operation of a well-constructed scraper line is one of sliding. The trough becomes smooth as glass from use, and the movement of coal is unaccompanied by any commotion. Now, admitting that the scraper consumes more power than the bucket conveyor, what have we to offset or compensate for this loss?



SUSPENDED FLIGHT CONVEYOR.

1. A simple, rugged construction, that will stand unlimited abuse and permits of a simple feed and a simple discharge.

2. A low first cost, not exceeding one-third that of a bucket conveyor of equal capacity, insuring a low interest and sinking fund charge.

3. Cheap repairs.

After all, that machine is best which shows the greatest net earnings; and the fact that scrapers are exclusively used in the largest coal handling region in the world by the producers of the coal, with whom the question of breakage of coal and repairs to machinery is of greater importance than to the consumer, is evidence sufficient that its usefulness is not yet at an end. Several improvements of scrapers have been made; most prominent among them the suspended flight conveyor, in which the entire weight of chain and scrapers is carried on guides outside the trough. These guides are covered with grease, and reduce the friction considerably, while the fact that the coal only is in contact with the trough insures greater durability.

Suspended flight conveyors are perfectly noiseless, are more economical of power, and cost less for repairs than the ordinary scraper; and while they cost a little more, they share the advantages of their prototype.

Flexible belt conveyors have a limited application as coal conveyors, and under certain conditions prove highly satisfactory. They do not permit of discharge at intermediate points, and have to be run at such speeds to get capacity that it results in considerable breakage at the delivery points. The belts are not durable, and charge for repairs consequently high.

Bucket, pan, and apron conveyors share both the advantages and the disadvantages of flexible belt conveyors, but owing to the material of which they are constructed, they are more durable as coal handling machines.

ENGINE AND BOILER TESTING.

HENRY W. SPANGLER.

Read November 19, 1898.

In these days of elaborate codes for the testing of engines and boilers we are apt to lose sight of the reasons for making such tests and to attempt to fulfil certain requirements that are entirely foreign to the reasonable purposes for which such tests are made.

Generally, all such can be divided into two classes—first, the so-called scientific tests; and, secondly, commercial tests. The first of these are such as are carried out by so-called original investigators, whose facilities are generally of the best, but applied in many cases to impossible apparatus, in a commercial sense. The objects of such tests are, nominally, to get at the real facts, on the basis of which greater advances in steam engineering are to be made. Unfortunately, the advance has seldom been made as the result of tests of this kind, and it is doubtful if scientific tests of the kind here referred to which will bear the sharpest scrutiny have been made by more than one investigator in a generation. By impossible apparatus, in a commercial sense, I mean that the self-imposed conditions are those which are very different from, and in many cases the direct opposite of, the conditions which actually prevail in apparatus intended for practical use. A concrete example will illustrate: In the proposed code for boiler testing now under revision by a committee of the A. S. M, E., a scientific test of the boiler may be commenced by hauling the fire.

Many of the so-called scientific engine-tests have been made on engines designed to be used for many different purposes, and the numerous by-passes, pockets, etc., required to fulfil the various functions leave the results obtained always open to criticism.

The second class of tests stands in an entirely different position, and it is on the results of these tests, intelligently carried out, that practically all the engineering advance is made.

Commercial testing has for its object the determining of one of two things—first, whether the apparatus is doing the best that can be done by it; or, secondly, whether a certain guarantee has been fulfilled.

These two tests are usually made by different persons and in the sequence above given, as in these days of sharp competition the guarantees furnished by the maker require for their fulfilment that the apparatus should be in first-rate condition. The result is that, generally, the engineer or the maker is called on to make the first of these tests, while the engineer who stands between the maker and the owner is called on to make the second. Much the higher grade of engineering skill is required for the first. The duty of the engineer in the first instance is not only to determine the facts, but to so modify the regimen of the apparatus that as many as possible of the unfavorable conditions may be eliminated and the favorable conditions made still more so. The business of the engineer in the second case is to report on the facts only. It is evident that the character of the tests made will differ in the two cases. In the one case all the facts, or as many as possible, must be obtained, while in the other only such as pertain to the guarantee.

In making the first set of tests the data obtained *must* be correct, or the object of the test will not be attained; in making the second set of tests the data should be as honestly obtained as in the first. The position of the engineer is quite a different one in the two cases: in the first, he must be honest with himself, and he has the confidence of his employer or client; while in the second case, if acting alone, he is liable to be looked on as the servant of the party who first suggested him, or, if acting with others, is very likely to be considered as a partizan. When the engineer feels that the latter is his position,—as, I am sorry to say, some do,—he is too likely to be a quibbler, straining every point that his employer may come out ahead; and one does not wonder that many so-called tests are looked on with suspicion. The position of the engineer in a case like the last is not at all an enviable one, and he must first know what is right and then do what he knows to be right.

The actual testing of boilers and engines is really a very simple matter. Direct methods of measuring the quantities to be dealt with are always to be chosen rather than indirect ones, and care should be taken to see that the apparatus in use is as nearly correct as can be obtained.

As tests of the second class above referred to are entirely covered by the first one, it is with that one alone that we will deal.

We will first take up a boiler which has been erected and is about to be tested. The maker wants to know whether it is in the best possible condition, and he wants to be able to tell this in the least possible time. There are usually two things required—first, that the boiler shall be able to do a certain maximum amount of work; and, secondly, that under certain definite conditions—as, for instance, when evaporating some part, say seventy-five or eighty per cent., of the maximum amount—it will do so with a given economy—as, for instance, utilizing sixty-five or seventy per cent. of the heat in the coal, and using a certain grade of coal. Unfortunately, it is not a very easy matter to state these conditions in such a way that they are entirely definite, and in many cases the results will vary with the meanings and limitations set to the terms of the contract.

For instance, if the contract says that seventy per cent. of the heat in the coal is to be utilized, what does this mean? and how is it to be determined? Is the moisture in the coal to be determined during the test by actually drying a large quantity, or by the the chemist's method, using a few grams? If by the first method, is it to be done by placing in the hottest part of the boiler-room or over a slow fire? It is safe to say that any one of these methods will give a different result and a correspondingly different value to the amount of heat that must be utilized.

Again, is the evaporation of this water to be allowed for or not? How is the heat in the coal to be determined—by chemical analysis or by actual burning in a calorimeter? Is the heat to be counted down to the initial temperature of the coal, which is the value usually obtained from the ordinary formulæ, or by the calorimeter, or only to the temperature of the steam? If by the first method, the lower the boiler pressure, the lower the actual efficiency; and if by the second, the greater.

It is clear that if the basis on which the efficiency is based is clearly stated, there can no such questions arise; but, ordinarily, they are all open questions for the engineer to decide.

As what we are after are the exact facts, it is probable that they will be most nearly reached by methods that lie between those ordinarily in vogue. That is, the amount of moisture in the coal should be determined by the chemist's method,—heating to something over 212° F.,—but on much larger samples, and before they are crushed for chemical analysis.

The heat in the coal is probably most nearly exactly determined if the coal is burned. The constants in the formulæ we have are not determined for the class of coals we use, and there is a considerable difference in opinion as to what the terms mean, anyway.

Knowing what we have to work with, the results obtainable in the actual boiler depend partly on the fireman. The latter factor is the one that makes the boiler tests unsatisfactory as compared with an engine test. Bad results may be obtained from a good fireman, but the reverse is seldom the case. It has not been possible until within a short time to measure the efficiency of the fireman as one of the factors in a boiler test, but it is believed that such data will soon be available. Assuming that a proper fireman has been selected to do the work, it is not sufficient simply to know the quantity of coal and water fed to a boiler, together with the minor data usually taken, as we supply the boiler with many more pounds of air than we do of coal and water combined, and it is possible that a boiler is inefficient because of its air supply in more cases than most of us dream of. Ordinarily, we supply one pound of coal, say eight pounds of water, and twenty pounds of air; and it is as necessary to have a check on the air supplied as on the coal or the water. It has not been possible to keep a very close watch on this until a method of continuously gaging the air was perfected, but it looks now as though such an apparatus is at hand.

The amount of air supplied increases the quantity of heat carried to the chimney for a given temperature; or, if the air supply can be reduced, allows a higher stack temperature with less loss, which would mean a greater capacity with the same economy, or the same capacity with greater economy.

To come down to details, the water should be weighed, and it is, perhaps, worth noting that, except for rough tests, the tank should never be allowed to fill to a certain mark, and the number of such tanks recorded. One of the most celebrated series of tests ever made is under the cloud of being worthless because of an incorrect tally of water tanks used on the test. The noting of the time at which anything is done is a good check on errors of this kind.

It is a wise plan to keep the time that water passes a definite mark in the lower tank, as this gives the rate at which the water is fed into the boiler, and allows a test to be started or stopped at any time.

Coal and ashes should, of course, be weighed, and when a number of boilers are being tested, it is worth while keeping separate accounts to locate any difficulty that may arise.

The only feasible way of determining the air supplied to a boiler is by the use of such apparatus as an econometer. The method of testing flue gases chemically is slow, and does not show the momentary changes taking place, and has always been found to be unsatisfactory.

This apparatus also enables us to determine the quantity of air in the flues at various points of their length, thus telling whether the air comes in at a proper place or not.

There are two other pieces of apparatus of value in testing boilers, but ordinarily their use is perfunctory; these are the stack thermometer and the draft gage. Generally, these readings are taken and set down and nothing further done with them. The thermometer should give the total pressure available for forcing air through the fire, and the draft gage the amount required to overcome the resistance of fire and passages, and to give the air velocity. There is not, necessarily, any relation between the quantities. With a stack 150 feet high, and with an outside temperature of 60°, the pressure due to the height of the chimney would vary with the temperature. Thus, with an inside temperature of 600° the total pull of the chimney is .91, while with 400° it would be .71 inches of water. I mean that with this temperature in the stack, and with the grate entirely closed so that no air could get to the chimney, this would be the pressure shown by a draft gage. This pressure is actually used up in overcoming the grate, fire, and flue friction, and in giving the air velocity. In a good boiler with a 150-foot stack these quantities might have the values of 1 for the flue friction, 12 for the grate and fire friction, and 1 for the portion required to give the air its velocity. As the opening through the grate is increased, the draft-gage reading will fall, until, finally, if all the resistance to the entrance of the air to the bottom of the stack were removed, the draft gage would read substantially zero. A high reading, therefore, means practically that the resistance to the passage of air through the grate is high, and nothing more.

The volume of air which a chimney will deliver will, therefore, not increase with the readings of the draft gage, but will increase with the temperature of the flue, and probably decrease with the increased reading of the draft gage, which differs from the ordinarily accepted ideas.

One other point worth remembering in boiler tests is the desirability of keeping conditions constant. It is surprising how nearly this can be accomplished with care on the part of the operator. One buys a boiler to deliver so much steam at a definite pressure. Ordinarily, this is understood to be the average an hour for, say, ten hours. For a single boiler this seems to be a mistake. For power purposes one does not want 3500 pounds of steam one hour and 2500 pounds the next from a 100 horse-power boiler, but 3000 pounds each hour; nor does one want a boiler which will blow off just after cleaning fires, and have the steam pressure drop from 100 pounds to 60 pounds while fires are being cleaned. To the user the latter condition is surely not satisfactory. One does not design a shaft from the average twisting a moment, but from the maximum; and while with one engine the difference between these quantities is great, with two it is not so much, and with three it is almost negligible. So, with one boiler in a plant the minimum rate should govern the size of the boiler for a given horse-power, and with two or more practically the average rate is what can be obtained.

Figure 1 shows the record of two tests—one with one 125 horse-power boiler and the other with two boilers of the same size and class. They were sold for this rating and, in the case of the single boiler, 94 horse-power with steam at 58 pounds is what could be depended on at all times, and not 125 horse-power at 100 pounds pressure. In the case of the upper diagram, the two boilers were improperly handled during the test, as they could have been so managed that 250 horse-power would have been continuously delivered instead of 350 at one time and 200 at another.

It is not a difficult matter, when testing more than one boiler, to keep the conditions substantially uniform. With a given steam pressure a steam pump can be made to deliver practically the same quantity of water each five or ten minutes. With a reducing valve, or by hand, the pressure on a boiler can be kept practically constant and the water level can be kept practically at the same point for the same condition of the fire.

There is one more detail of boiler testing that is worth speaking of, and that is the method of starting and stopping a test. The method of hauling fires at the beginning and end of a test is simply barbarous; and when one attempts to decide that there are so many pounds of combustible in the material hauled from the fire, he is, perhaps, unconsciously straining his judgment. Whenever one "judges," he guesses, and that is outside the province of the class of tests here spoken of. The other standard method is by judging the fire at the beginning and end of the test, and allowing the difference. In a capacity test

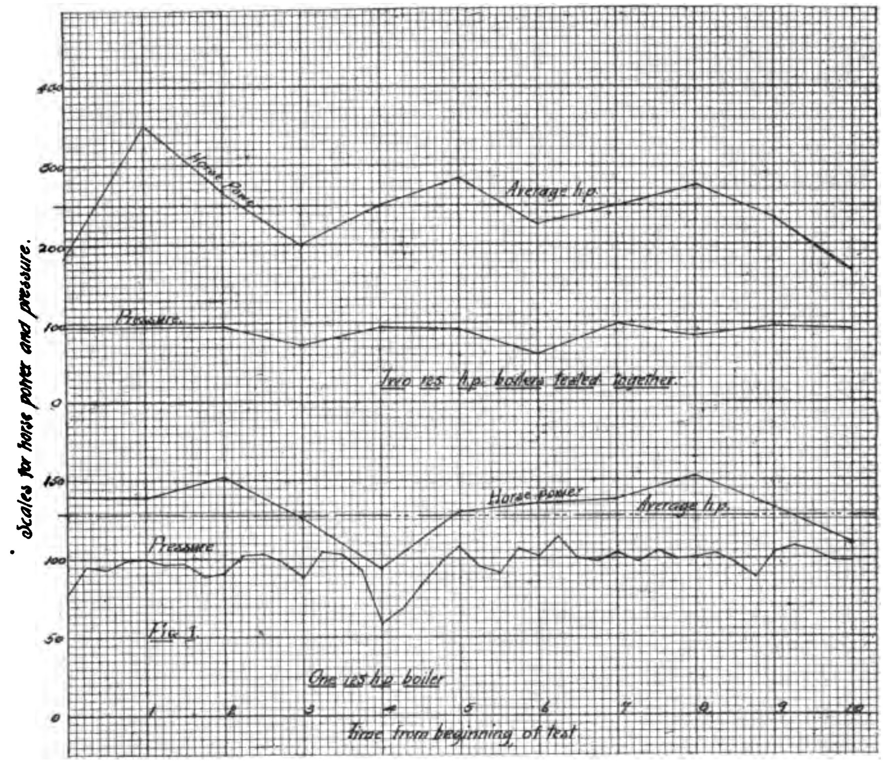


FIG. 1.—BOILER TESTS.

the allowance makes little difference; but in an economy test the greater the allowance, the greater the economy.

There is a third method which has been practised for many years which is fair to both boiler and prospective owner, and has been well thought of by some boiler-makers. It is much more tiring on the engineer conducting the test; but that he can charge for, if he pleases. The scheme is this: Suppose we have a 100 horse-power boiler to test for capacity, test to run from 8 A. M. to 6 P. M. The coal is such that the fires are to be cleaned twice in the test. Fire should be on the boiler twenty-four hours before the test begins. Beginning at 2 A. M., the boiler should be fired at about its capacity. Roughly, 400 pounds of coal should be burned each hour from 2 A. M. until 7 A. M. It is not necessary that any account should be taken of water, nor any other data for test purposes. All we want is heavy, dirty fires at 7 A. M. At 6.30 the water level is brought to the point at which it is to be carried, and is kept there, and all conditions brought to running conditions. At 7 begin cleaning fires. Put, say, 400 pounds of coal on the floor and allow the fireman to use it to the best advantage. Note the time he begins using the next lot of coal. Say this is 8 A. M. This is the time at which the test really begins. At 5 P. M. clean fires again and weigh out 400 pounds of coal, the same amount as in the morning. See that it is all used up by 6 P. M., when the test ends. The fire at the end of the test will then be as nearly in the same condition as at the beginning of the test as it is possible to make it, barring the fatigue of the fireman.

This seems more intricate than the standard methods, but neither the boiler nor the results can be jockeyed.

In this connection emphasis should be put on keeping the water level constant. This is particularly necessary at the beginning and end of the test, and unless the person making the test stands over the pump at this time, it is not likely to be done. We have all seen the water level kept below the mark, and at the end of the test the pump started as fast as it will go to bring the level to the right place; and we have all seen the feed-pump stopped at the beginning of the test, to bring the water down to right starting-point. The result is that at the beginning of the test the boiler had the least weight of water in it, and at the end the most, the difference being apparently evaporated, but in reality being in the boiler.

I have said nothing about the quality of the steam produced. I think it is quite safe to say that with the usual proportions now found, and with the boiler worked at or within its capacity, practically dry steam will be given by any of the common type of boilers. It must be remembered, however, that any apparatus only gives the moisture in the sample it receives, and if it be so connected that it receives the drip from the pipe itself, it will show the moisture in that sample.

A Barrus universal calorimeter will probably give the best results—most accurate, I mean—of any apparatus we have. There is one point in the use of it, however, which is puzzling, and that is, what to do with the readings after you get them; how really to determine the moisture percentage.

For instance, a set of readings will average up as shown in the first line of the little table herewith. The second line is the average taken after the boiler is shut off the line and no steam is going out of it. It is usually inconvenient to make the pressure the same for the two lines. The object of taking the second line is to find out how much moisture is due to the instrument itself. In many cases, all that shows is due to the instrument, while without the correction there would apparently be two or three per cent. of moisture—in this case one and six-tenth per cent.

	P.	UPPER T.	LOWER T.
During test, ...	112	330	264
After test, ...	129	340	280

It will be noted, on looking up the steam tables, that 112 pounds pressure corresponds to 335.2 degrees, and 129 pounds to 346.5 degrees, or the upper thermometer does not register the temperature of the steam. This is a common condition of affairs, and is due to the radiation for the exposed stem of the thermometer.

Correcting for this radiation, we have—

112	335.2	269.2
129	346.5	286.5

To correct for difference in pressure, we have: Total heat at 112 pounds, 1184.4, and at 129 pounds, 1187.6, a difference of 3.2 heat units. But 3.2 heat units will superheat a pound of steam 6.7°, and, correcting for pressures, we have—

112	335.2	269.2
112	335.2	279.8

The difference in the last two numbers is the loss in superheating, due to the moisture in the steam, or this corresponds to a moisture percentage of $\frac{10.6 \times .48 \times 100}{877.8 \text{ (latent heat at 112)}} = .6$ per cent. That is, the steam is practically dry.

In engine testing very much the same character of tests are made. One is to determine whether certain results are obtained or not; the other to determine whether the economy of the engine can be improved —that is, to put the engine in its best shape. As in boiler testing, these tests are ordinarily made by different persons, and the second requires much the greater engineering skill.

We are all sufficiently familiar with indicator cards to know that all they give is the relation between the pressure in the cylinder and the volume swept through. The horse-power, the general conditions of the distribution of steam, can be determined, but the economy of the engine is still an unknown matter. It is absolutely impossible to tell how much steam is being used by the engine from the cards. The volume, or weight, actually in the cylinder in the shape of steam can be determined, but it is well known that there is a large amount of moisture in the shape of water actually passing through the cylinder, and this may be from twenty-five to forty per cent. of all the steam used, if the engine is known to be tight.

To determine the weight of steam used there is only one thing to be done if satisfactory results are desired, and that is to weigh the steam after it has passed through the engine and been condensed in a surface condenser. This credits the engine with all leaks between the engine and condenser; but this can not be avoided. It often happens that this is not practicable, and we must weigh the water fed to the boiler. As the steam line is generally much longer and much more complicated than the exhaust line, the error against the engine this time is much greater than the error in its favor when a condenser is used.

It is often suggested that the line leakage can be determined by shutting down the engine and noting the difference in water level in the boiler some time after the test is ended. One does not try this experiment very often, as, from what has been said on the question of water level in boilers, it is easily seen that for a long time after the plant has been shut down the water level is as likely to go up as to go down; and the going down, when it does occur, is as likely to be due to a cooling boiler as to leaks.

We all know that a large portion of the heat going into the cylinder is rejected at the end of the stroke; but how to improve it, how to get a better return for the heat expended, has been the problem, and until very lately we have been groping entirely in the dark.

Taking a given engine, we take indicator cards and measure the water consumption. We compare the two and decide, from what we know of other engines, that the water consumption is too great. Where do we begin to try to improve it? We try a little longer cut-off and a little more compression, or a little shorter cut-off and less compression. If we get less water consumption, we continue on the same line; but how much of it is due to the cut-off, and how much to the compression, we have no means of knowing. We try jackets with low pressure and with higher: if the jacket temperature is as high as that of the steam given to the cylinder, why should it not be higher, and much higher?

Probably, one of the first tangible results of the study of the internal workings of an engine are embodied in what is known as Hirn's analysis. This is an attempt to determine, analytically, certain results which, when plotted, show graphically what actually takes place inside the steam cylinder. The idea was something like this: When the steam valve opened, there was already a certain amount of steam closed up in the clearance space. This represented a definite amount of energy. The incoming steam brings in a certain additional amount of energy, and at the point of cut-off the total energy to be accounted for was equal to the external work done up to that point, added to the heat still in the steam and that given to the cylinder walls.

During expansion at any point, the work done, added to the heat left in the steam, is equal to the heat at the beginning of the expansion plus or minus, as the case might be, the amount of heat received from the cylinder walls, and so on around the entire cycle.

The representation of this diagrammatically was quite unsatisfactory, and really gave one little clue as to what was taking place in the cylinder. In figure 2 we have an indicator card with such an analysis, and will try to follow out the series of changes as are here referred to.

Starting at *a*, for convenience, during the expansion generally, heat is given up by the cylinder walls. If we know the quantity of steam and water present at *a*, we know it through the entire expansion. This quantity is evidently equal to that received from the boilers,

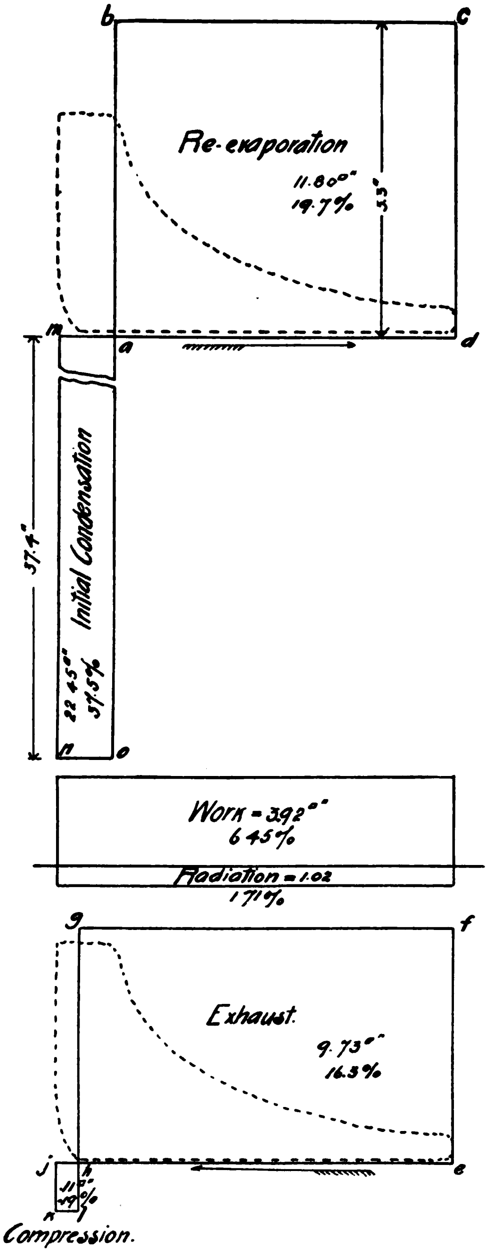


FIG. 2.—HIRN'S ANALYSIS.

added to what is in the clearance space at *h*. It is, therefore, possible to draw a diagram, such as that in the figure, showing the heat interchange between the cylinder walls and the steam. The upper part of the diagram represents the heat exchange along the stroke to the right, and the lower, the return stroke. Call all areas above the line heat added to steam, and all below, heat taken away from the steam. We know that, generally, during expansion there may be, first, heat given to the walls, and, later, heat given to the steam, and the diagram takes the form *a b c d*, the area being the net heat received by the steam. At *d* the exhaust valve is open, a large amount of heat is given to the steam, and on the return stroke additional heat is given to the steam and some work is done on it, and the diagram takes the shape *e f g h*. From *h* to *j* heat is generally being given to the cylinder walls, and the diagram takes the shape *h j k l*. Now the valve opens and steam is admitted. A large quantity of heat is given to the cylinder walls up to the point of cut-off; *m a o n* represent the total quantity of this heat. Evidently, if the sum of the areas above and below the lines are equal, no heat is lost and no additional heat is received. If the upper area is the greater, a jacket is used; if less, there is radiation, and the amount of these can be determined. This was probably the first step, and enabled us to make some estimate as to where the heat went and what it actually accomplished. It was, however, a long step in the right direction.

The work is tedious and requires a lot of calculations to put it in the shape here shown.

The invention of the entropy-temperature diagram, first put in practical form by Mr. S. A. Reeve, changed all this and put exactly the same thing into much better shape and enabled us to locate, in addition, the exact place of many of the changes.

Imagine a diagram whose ordinates are temperature and whose area represents heat. The abscissæ are what is called entropy, and hence the name. In figure 3, suppose we have an indicator card from an engine such that the expansion and compression are complete and are adiabatics, for instance.

a and *b* of the upper figure are at the same temperature; therefore, *a′ b′* is a horizontal line in the second. *b c* is an adiabatic (no heat is added or taken away), therefore *b′ c′* is a vertical line; *c d* is a constant temperature line, therefore *c′ d′* is a horizontal line. As the steam is raised to the pressure a in the boiler and not in the cylinder, $d'\,a'$ is the closing line of the diagram. The area $a\,b\,c\,d$ is exactly equal to $a'\,b'\,c'\,d'$.

If $b'\,c'$ inclines to the right, heat is added from b to c; if to the left, heat is taken away. If $d'\,c'$ inclines down to the left, heat is not taken away fast enough, etc.

Taking the indicator card from the same engine, as before, we have figure 4 representing the heat interchanges.

In this figure the diagram marked "Actual Cards" is a sample card taken during the test, that marked " Mean Card " is the average of all the cards taken, and that marked "Heat Distribution" is an entropy diagram, such as we have been referring to. Corresponding letters refer to the same event in the stroke. At a steam is admitted, at b stroke begins, at c cut-off takes place, at d the exhaust opens, at e the pressure has reached the back-pressure line, and at g compression begins. Following around the upper diagrams, we have lost heat at every portion of the stroke except during the expansion, that due to initial condensation ($c\,k\,l\,o$) being sixty per cent. of all the heat added. It is worth noting that the efficiency of the engine is about fifty per

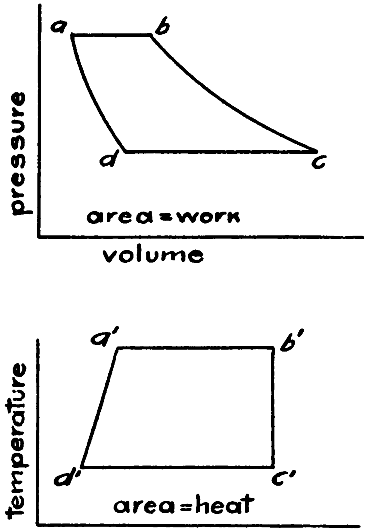


Fig. 3.—Work and Heat Diagrams.

cent., or the work done is one-half that possible in any engine working between these temperature limits.

The small areas marked "Scale" show the same amount of work on each of the three diagrams.

Another point often desired in engine testing is to determine the regularity of speed. In the use of some engines this is a matter of moment, while with others it is not. In specifications one finds such a clause as "the speed shall not vary over three per cent."; in others the same clause, with the words "from the rated speed." Both are clear, but the additional words double the possible variation. Of course, a continuous record would be desirable; but, generally, records of this class are qualitative rather than quantitative, and the calibration of the apparatus is not at all convenient, and, finally, the calibration comes down to some system of counting. Practically, we can

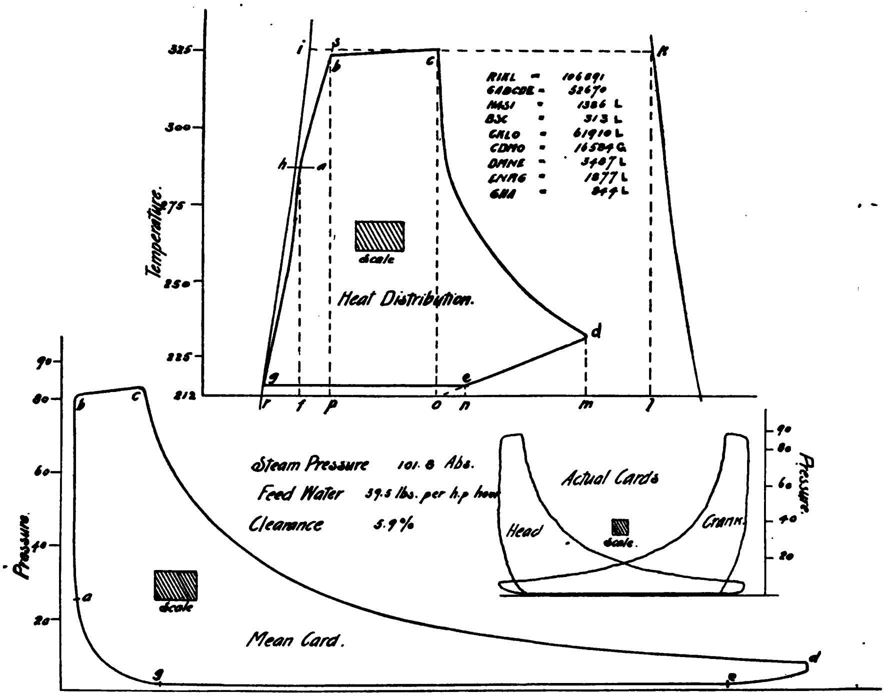


Fig. 4.—Work and Heat Diagrams.

conveniently count the number of turns and separate them into intervals as small as we please. The average for each such time-interval is usually taken for the speed during that interval. With a well-regulated engine, the variations in the speed taken in this way are not great, do not occur suddenly, and do not have a very great effect on the running of the plant. For lighting purposes especially, the variation in speed, due to sudden changes of load, is of more moment. Probably the best way to judge of the effects of such a change in speed is by the indicator. By opening a switch to throw off any desired proportion of the load and, at the same time, throwing in the indicator, a series of diagrams will be traced showing the rapidity with which the regulating mechanism does its work and the certainty with which the governor acts. Cards taken just before and just after such a change in load will locate on the varying card the initial and final conditions which, with a hunting governor, are not generally the greatest and least diagram drawn.

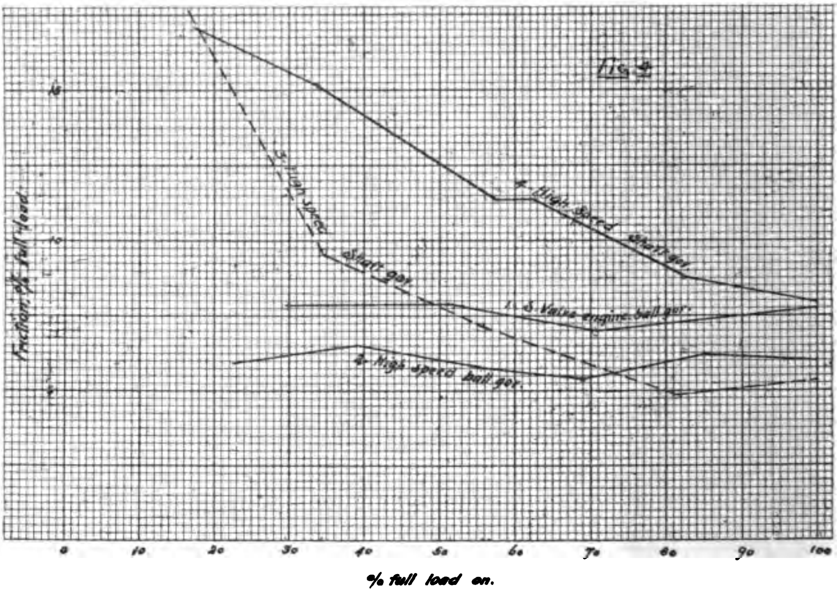


FIG. 5.—FRICTION LOADS.

The net horse-power delivered by an engine is often desired. There is only one way of properly determining this, and that is by using a Prony brake. Up to, perhaps, 150 or 200 horse-power this can be satisfactorily managed; but for larger engines, and for engines directly connected to the apparatus driven, the thing usually done is to run the engine light and assume that this is always the work used up in friction. This is not always a safe course, however. Here are the records of some tests which will illustrate this:

The diagram (Fig. 5) is drawn with "percentage of full load" for abscissæ, and the "friction in per cent. of the full load" for ordinates. The curves are marked to show the class of engine from which they are taken. The two that are nearly horizontal are from engines driven by fly-ball governors, while the other two are driven by centrifugal shaft governors.

It would be safe in the first and second cases to take the initial friction as the loaded friction, but entirely wrong in the third and fourth examples. The engines in each case were run to their capacity.

In conclusion, we have dealt here only with methods of determining facts, or as near to the truth as the apparatus at hand will allow. To make use of these facts—or, in other words, to deduce conclusions from them—is a subject that most of us try to master, but few accomplish successfully.

DISCUSSION.

James Christie.—I understood Prof. Spangler to state some time ago that he had reason to believe that the losses from condensation, or heat-transference, in steam-engines were largely independent of the velocity of the steam through the cylinders; in other words, that the heat losses in slow-speed engines were proportionately not much, if any, greater than in high-speed engines. As the opposite view is commonly held, I wish to ask if my recollection is correct, and if he still holds that opinion.

Prof. Spangler—I think that Mr. Christie's question can probably be best answered by the last clause in my paper. As to the amount of steam used in the steam cylinder, my own opinions are entirely heretical, and I do not think it safe to start a discussion on that subject. I do believe, however, that the reasons that compound and triple-expansion engines are successful are entirely different from those usually given. Most of you probably remember the test that was made on some Corliss engines a number of years ago in Cincinnati by Mr. Hill. These engines were as well made as any could be. They were tight, if engines ever were made tight. The result shows that of the steam that went through the engines, thirty-three per cent. must have been water when the valve closed. These engines were Corliss and slow speed. A short time ago I made a test of a 500 horse-power engine, using steam at high enough pressure to use triple-expansion successfully, and the percentage of moisture in that engine when the high-pressure valve closed was almost exactly thirty per cent. ; and this also was a successful engine. This is one of the reasons, among others, that nclined me to the belief that stage-expansion, as it is called, does not in itself reduce initial condensation.

JOSIAH DOW.—Have you any information, from the work being done in steam-engines, as to the influence of time on the cycle losses? That is, whether a high-speed engine would lose less during these cycle losses than a slow-speed engine?

PROF. SPANGLER.—I have no data at hand, but I think it could be worked out for low speeds from a series of tests made a few years ago, the results of which were published in the "Transactions of the American Society of Mechanical Engineers," Vol. x, 1888–'89. An engine was run with varying speeds and loads. I had intended to say that the question of graphic representation of the entropy in the form given in the paper is comparatively new. It was hinted at a number of years ago, but I think in a form that failed to impress any one with the value to be gained from it. I am sure that the next few years' investigation will tell us much more about what actually takes place in a steam-engine than we have ever known. I do not know that this is the method by which it will be done, but it is another step in that direction.

W. H. LEWIS.—Could there be any reduction in the amount of bearing pressure as the load increases?

PROF. SPANGLER.—There are a number of cases in which the actual indicated horse-power used up in friction does decrease as the load increases. So far as I know, the indicator card was right and the Prony brake was right, and the methods used were correct. The results in the paper are from data that I have obtained from actual tests.

MR. LEWIS.—Would it be due to the warming-up of the journals?

PROF. SPANGLER.—No. Tests were made before as well as after the engine had reached its normal condition.

L. F. RONDINELLA.—Generally, the frictional horse-power is taken as the quantity given with no load.

PROF. SPANGLER.—As to whether this is correct or not, depends on the type of the engine. The no-load friction would be safe to use with certain types of engines and would not be safe with others. The diagrams in the paper are for the engine alone, and not for an engine directly connected to another piece of apparatus.

NOTES AND COMMUNICATIONS.

Recent Developments in Electrical Engineering.

At the meeting of November 5th Mr. Carl Hering began some informal remarks on "Recent Developments in Electrical Engineering," in which he intended to review briefly those developments which have a direct bearing on the other branches of engineering.

Owing to the lateness of the hour, the present portion was limited to electric traction. After calling attention briefly to the phenomenally rapid development of the overhead trolley system, and giving some statistics, he showed that its chief competitors in densely built-up cities—namely, the conduit and a modified accumulator system—had recently been so perfected as to be now recognized as commercially practicable systems, especially the former, which is in regular use in several cities and is being introduced to a large extent in New York City, where it is fast replacing all the recently built cable roads. The only serious objection to the conduit system seems to be the great first cost as compared with that of the overhead trolley system ; on the other hand, a very important advantage lies in the fact that both the lead and return wires are generally insulated, whereby the corrosion of underground water- and gas-pipes, by the return currents, is entirely avoided. While there are only a few regular accumulator lines in use, the commercial success of which does not yet seem assured beyond a doubt, there are several so-called "mixed systems" in use, notably in Hanover, Dresden, and Paris, which seem to be quite successful. In these the overhead trolley and the accumulator systems are combined, the latter being used for the densely built-up portion of the city, where the overhead wire is considered objectionable, while the trolley system is installed in the outlying portions. The accumulators are charged from the trolley line while the car is being run from that line. Present progress in the so-called surface contact systems seems to be limited to the making of inventions ; there seems to be only one short line of this kind in actual operation—namely, at Monaco. Electric traction, he stated, has not only replaced horse traction, but is fast replacing the cable system, the legitimate field for which is being rapidly reduced to very narrow limits.

In the application of electricity to what may be called heavy traction, such as on the present steam railroads, progress has not been so rapid as was expected. What has been done, however, seems to have been very successful, and developments seem to be assured, in certain directions, at least ; among these are the application on short lines with dense traffic, on feeders for steam railways, and over grades that are too steep for a locomotive with a train ; on such lines electric traction is already a very serious competitor to steam traction. Even on some of the longer through lines electricity is now being introduced, notably in Italy, Hungary, Belgium, and Switzerland. Steep grades being less objectionable in electric than in steam traction, the construction of the road is simplified and the cost reduced ; an electric road may be built over a mountain, while a steam road would have to go around it or through an expensive tunnel.

Very high speed traction, for which electric power is much better adapted than steam, seems to have made little or no progress. A number of elaborate projects have been worked out, but they are still only on paper. The difficulties encountered seem to be of a financial rather than of an engineering nature, as curves and grades must be avoided, and that is expensive.

Electricity is replacing steam on elevated roads, but both kinds of elevated roads seem to be seriously affected by the electrically operated surface roads, which are more convenient, and in general only slightly less rapid, when the time in going to and from the stations is considered. It is probably only under specially favorable conditions, such as exist in New York City, that elevated roads will continue to hold their field. For underground lines nothing but electricity would be considered, the new cable line in Glasgow being a notable exception.

For very steep mountain roads the three-phase alternating current system is being used, apparently with success, especially in Switzerland; and it seems likely that no more new roads of this nature will be built for steam traction. In such regions cheap water-power is generally available. This cheap power, and the greatly reduced dead weight of the locomotive, give electric traction important advantages over steam-power on mountain roads. The best example of this kind of a road—namely, the railway up the Jungfrau, one of the highest of the Alps—was described and some of the engineering data were given. The difficulties encountered in the glaciers, snow fields, and avalanches were shown by means of a lantern slide. The first part of the road was finished this summer, and it is expected that it will all be completed in the course of several years. Electricity is used very largely in the construction, both for power and for heating purposes. All the power is to be derived from water-falls.

The remainder of the remarks will discuss in a similar way the progress in the transmission, generation, and application of power, in dynamos, direct conversion, light, heat, and electrometallurgy.

ABSTRACT OF THE MINUTES OF THE CLUB.

REGULAR MEETING, September 17, 1898.—The President in the chair. Fifty-nine members and visitors present. The subject of "The Proper Proportions of Parts of Steam-engines" was discussed by Messrs. Vail, Schumann, Dow, Christie, Luders, Eglin, Nichols, Marburg, and Robinson.

BUSINESS MEETING, October 1, 1898.—The President in the chair. Fifty-seven members and visitors present. The tellers reported that Messrs. J. W. Lucas, A. H. Mainwaring, and Philip L. Spalding had been elected to active membership, and Mr. J. W. Ridpath to associate membership.

Mr. Josiah Dow read a paper on the "Dow Steam-engine and Chronometric Governor." The subject was discussed by Mr. Francis Schumann.

Mr. J. C. Trautwine, Jr., read by title a paper on "Popular Errors about Water Meters."

REGULAR MEETING, October 15, 1898.—The President in the chair. One hundred and thirteen members and visitors present. Mr. Geo. S. Webster presented a paper on "The Construction of the Pennsylvania Avenue Subway and Tunnel, Philadelphia." The paper was largely illustrated by lantern views.

Mr. Allen J. Fuller described the changes which had been made necessary in water-mains by the construction of this subway.

The subject was also discussed by Messrs. Trautwine and Schermerhorn.

BUSINESS MEETING, November 5, 1898.—The President in the chair. Seventy-three members and visitors present. The following amendments to the By-laws were offered and laid over under the rules:

To amend Article VII, Section 1, by substituting:

"Any member whose dues remain unpaid on the first day of May shall be notified by the Treasurer, and his name posted in the Club-house. If the dues of a member so notified remain unpaid by the first day of June, his name shall be dropped from the list of members, and he shall cease to be a member of the Club; *Provided*, that, at the discretion of the Board of Directors, the time for payment may be extended under such conditions as the Board may determine."

"In case of such forfeiture of membership, notice shall be sent to him in writing that he has ceased to be a member, specifying the reason thereof; and he shall thereupon forfeit all his right, title, and interest in and to all the property and assets of the Club."

To amend Article VII, Section 2, by striking it out.

To amend Article VII, Sections 3, 4, and 5, by renumbering them respectively 2, 3, and 4.

To amend Article IV, Section 1, by substituting the word "eight" for the word "six."

To amend Article V, Section 9, by substituting the word "four" for the word "three," and adding: "At the Annual Meeting in 1899 five directors shall be elected, four to serve for two years and one to serve for one year from the time of election; the determination of those to serve for the longer or shorter period may be made either upon the nomination papers or by lot after election."

The tellers reported the election of M. E. Hibbs to active membership and Theo. Bunker to junior membership.

Mr. Charles Piez read a paper on "Coal-handling Machinery."

Mr. Carl Hering presented "Notes on Recent Progress in Electrical Engineering."

REGULAR MEETING, November 19, 1898.—The President in the chair. Ninety-five members and visitors present. The Secretary announced the death of Mr. Leighton Lee, an active member, which occurred in Chicago on November 15th as the result of an accident.

Prof. H. W. Spangler read a paper on "Engine and Boiler Testing." The subject was discussed by Messrs. Christie, Schumann, Dow, and Lewis.

BUSINESS MEETING, December 3, 1898.—The President in the chair. Forty-nine members and visitors present. Nominations for officers for 1899 were presented in writing, as prescribed by the By-laws, as follows:

For President:	*Proposed by:*	*Seconded by:*
FRANCIS SCHUMANN.	James Christie.	Edwin F. Smith.
For Vice-President:		
HENRY LEFFMANN.	Carl Hering.	Josiah Dow.
For Secretary:		
L. F. RONDINELLA.	Wm. C. L. Eglin.	Richard L. Humphrey.
For Treasurer:		
GEO. T. GWILLIAM.	Wm. C. L. Eglin.	W. B. Riegner.
For Directors:		
H. M. CHANCE.	Benj. Smith Lyman.	Edgar Marburg.
CLARK DILLENBECK.	Edwin F. Smith.	Harrison Souder.
WM. PENN EVANS.	A. Falkenau.	James Christie.
MINFORD LEVIS.	Henry Leffmann.	Geo. T. Gwilliam.
CHARLES PIEZ.	G. S. Webster.	Edgar Marburg.
HARRISON SOUDER.	John Birkinbine.	Richard G. Develin.
W. L. WEBB.	John Birkinbine.	W. P. Dallett.

Mr. R. W. Lesley presented a paper on "Cement and Cement-testing Laboratories." The discussion of the paper was postponed until Saturday, December 17th, and by resolution this was made an adjourned business meeting, for the further discussion of various amendments.

ADJOURNED BUSINESS MEETING, December 17, 1898.—The President in the chair. Forty-six members and visitors present. The various amendments which had been offered to the By-laws were, upon motion, laid upon the table.

Mr. R. W. Lesley exhibited and explained a considerable number of lantern slides relating to cement testing, after which there was a general discussion upon the subject of cement and its qualities. Messrs. Little, Schermerhorn, Souder, Humphrey, Leffmann, Gill, and others took part in the discussion.

ABSTRACT OF THE MINUTES OF THE BOARD OF DIRECTORS.

REGULAR MEETING, September 17, 1898.—Present: The President, the Vice-Presidents, Directors Schumann, Levis, Humphrey, and Ott, and the Secretary and the Treasurer.

The Treasurer's report showed:

Balance on hand, August 31, 1898, ... $775.94

Provision was made for the proper keeping of the $500 United States war-loan bond recently purchased as an investment.

The Publication Committee was authorized to institute legal proceedings against any person delinquent in advertising contracts.

REGULAR MEETING, October 15, 1898.—Present: The Vice-Presidents, Directors Hartley, Schumann, Levis, Humphrey, and Ott, the Secretary, and the Treasurer. The first Vice-President in the chair.

The Treasurer's report showed:

Balance on hand, September 30, 1898, ... $729.38

Routine business was transacted.

REGULAR MEETING, November 19, 1898.—Present: The President, the first Vice-President, Directors Schumann, Levis, Humphrey, and Smith, the Secretary, and the Treasurer.

The Treasurer's report showed:

Balance on hand, October 31, 1898, ... $486.83

Resignations of membership from Messrs. John Graham, Jr., Paul C. Brewer, Nelson Macy, and Edward B. Ives were accepted.

The Secretary reported the death on November 15th of Mr. Leighton Lee, active member of the Club since March 5, 1898.

The Publication Committee reported that the fifth and last number of Vol. XV, to be issued in the early part of January, will contain all matter prepared for publication up to the close of the current year.

REGULAR MEETING, December 17, 1898.—Present: The President, the first Vice-President, Directors Hartley, Levis, Schumann, Ott, Humphrey, and Smith, the Secretary, and the Treasurer.

The Treasurer's report showed balance on hand, November 30, 1898, of $835.48.

A special committee, consisting of the chairman of each standing committee, with the chairman of the Publication Committee as chairman thereof, was appointed to prepare the Annual Report, and a special meeting was ordered on January 7th, at 3 P. M., to consider this report and prepare it for publication.

ADDITIONS TO THE LIBRARY.

FROM THE NEW YORK ACADEMY OF SCIENCES.

Vol. XI, Part 2.

FROM THE BUREAU OF SURVEYS, PHILADELPHIA.

Annual Report, 1897.

FROM THE UNITED STATES GEOLOGICAL SURVEY.

Bulletins 88–89–149, Monograph XXX.

FROM THE NEW YORK ACADEMY OF SCIENCES.

Vol. X, Nos. 1–12.

FROM THE INSTITUTION OF CIVIL ENGINEERS, LONDON.

Pumping Station at Siena Almagrera. Abstracts of Papers in Scientific Transactions and Periodicals. Land Slides in British Columbia—Stanton. Locomotive Fire Boxes—Thow. Locomotive Slide Valves—Aspinall. Alternate Current Motors—Atkinson. Dublin Electric Tramway—Parshall. Railway Surveying in Tropical Forests—Shelford. Evolution of the Locomotive Engine—Marshall. Longitude in Land Surveying—Downes. Channels through Sandy Estuaries—Crosthwaite. Section No. 1, North Yarra Main Sewer—Champion. Monier System of Construction—Beer. Laying out Transition Curves—Robinson.

FROM THE STATE BOARD OF HEALTH, MASSACHUSETTS.

Twenty-ninth Annual Report.

FROM THE DEPARTMENT OF THE INTERIOR, WASHINGTON.

Water Supply and Irrigation Papers Nos. 17 and 18. Irrigation near Bakersfield, Cal. Irrigation near Fresno, Cal.

FROM THE GEOLOGICAL SURVEY OF CANADA.

Annual Report, 1896, Vol. IX.

FROM THE SECRETARY OF INTERNAL AFFAIRS, STATE OF PENNSYLVANIA.

Annual Report, 1897.

FROM THE NEW YORK ACADEMY OF SCIENCES.

Transactions, Vol. XVI, 1896–'97.

FROM THE STATE GEOLOGIST OF INDIANA.

Twenty-second Annual Report, 1897.

FROM THE INSTITUTION OF CIVIL ENGINEERS, LONDON.

Manufacture of Cordite—Anderson. Cooling Reservoirs for Condensing Engines—Barker. Iron, Steel, and Copper when acting as Boiler Plates—Bryant. Railway Construction in New South Wales—Burge. Finer Grinding of Portland Cement—Butler. Law of Condensation of Steam—Callendar and Nicolson. New Transmission Dynamometer—Dalby. Simla Water Works—Goument. Amballa Water Works—Goument. Cement Concrete—Preston. Re-erection of the Albert Bridge—Brisbane—Stanley. Automatic Inclines and Railway, Junin, Chile—Harding. Railway Construction through Bog-land—Howley. Reservoirs in Western India—Strange. Abstracts of Papers in Scientific Transactions and Periodicals.

FROM THE LIVERPOOL ENGINEERING SOCIETY.

Transactions, Vol. XIX.

FROM THE COMMISSIONER OF PATENTS.

Annual Report, 1897.

FROM THE GEOLOGICAL SURVEY OF NEW JERSEY.

Annual Report, 1897.

FROM THE MASTER CAR BUILDERS' ASSOCIATION.

Proceedings, 1898.

FROM L'ASSOCIATION TECHNIQUE MARITIME.

Proceedings, 1897.

FROM THE WAGNER FREE INSTITUTE OF SCIENCE, PHILADELPHIA.

Transactions, Vol. III, Part IV, April, 1898.

FROM THE ENGINEERING ASSOCIATION OF THE SOUTH.

Proceedings, Vol. IX, No. 6.

FROM THE UNITED STATES GEOLOGICAL SURVEY.

Bulletin No. 150—The Educational Series of Rock Specimens Collected and Distributed by the United States Geological Survey—Diller. Bulletin No. 151—The Lower Cretaceous Gryphaes of the Texas Region—Hill and Vaughan. Bulletin No. 152—A Catalogue of the Cretaceous and Tertiary Plants of North America—Knowlton. Bulletin No. 153—A Bibliographic Index of North American Carboniferous Invertebrates—Weller. Bulletin No. 154—A Gazetteer of Kansas—Gannett. Bulletin No. 155—Earthquakes in California in 1896 and 1897—Perrine. Bulletin No. 156—Bibliography and Index of North American Geology, Paleontology, Petrology, and Mineralogy for 1897—Weeks.

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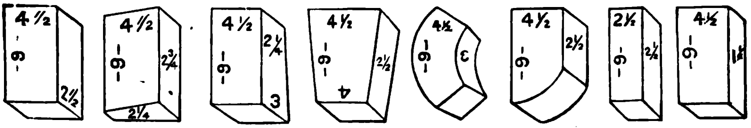

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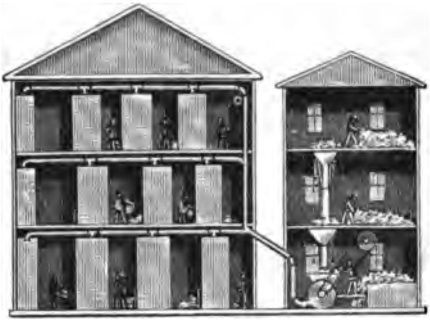

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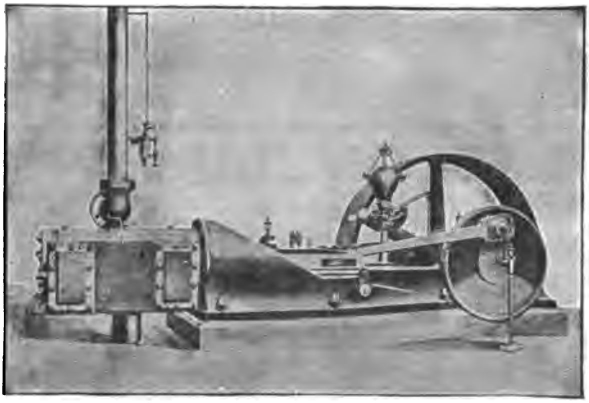

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Machine Tools
FOR ACCURATE WORK

Testing Machines
Mechanical Stokers
Boring Mills
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Cranes { Hand Steam Belt
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MEETINGS

Annual Meeting—3d Saturday of January, at 8 P.M.

Stated Meetings—1st and 3d Saturdays of each month, at 8 P.M., except between the fourteenth days of June and September.

Business Meetings—When required by the Constitution or By-Laws, when ordered by the President or the Board of Directors, or on the written request of five Active Members of the Club.

The Board of Directors meets at 4 P.M. on the 3d Saturday of each month, except July and August.

Saylor's Portland Cement

Manufactured by COPLAY CEMENT COMPANY

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USED ON THE FOLLOWING OPERATIONS:

New York Docks, Geo. S. Green, Jr., C. Engr.	13,000	barrels.
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Concrete Mississippi Jetties, Capt. J. B. Eads, C. Engr. E. L. Corthell, 1st A. Engr.	12,000	"
Edgar Thompson Steel Works, Carnegie Brothers, Proprs.	16,000	"
New York & Brooklyn Bridge, C. C. Martin, 1st A. Engr.	1,700	"
Croton Aqueduct, New York, J. C. Campbell, Isaac Newton, Engineers.	6,500	"
Concrete Sandy Hook Jetties, Col. G. L. Gillespie, Engr.	2,000	"
New Capitol, Albany, N. Y., I. G. Perry, Superintendent.	15,000	"
New Mutual Life Insurance Co.'s Building, N. Y., C. W. Clinton, Architect.	3,000	"

Old Orchard Shoal Lighthouse, Major D. Heap, Engr.	2,000	barrels.
Delaware & Hudson Canal Co., A. J. Swift, Engr.	20,000	"
Reading Railroad Terminal, Philadelphia, Pa. Wilson Bros. & Co., Engrs.	10,000	"
Deaf and Dumb Asylum, Mt. Airy, Wilson Bros. & Co., Engrs.	2,500	"
County Prison, Holmesburg, Philadelphia, Wilson Bros. & Co., Engrs.	7,000	"
House of Refuge, Glen Mills, Pa., Cope & Stewardson, Archts.	2,500	"
Harrison Block, Philadelphia, Cope & Stewardson, Archts.	5,000	"
Kirschbaum Building, Philad'a., Frank Watson, Archt.	4,000	"
Concrete Wall, League Island Navy Yard, C. C. Wolcott, Engr.	1,500	"

DIPLOMA AND MEDAL CENTENNIAL EXPOSITION PHILADELPHIA 1876.

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